AMERICAN GUIDED MISSILES OF WORLD WAR II

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ILLUSTRATED BY JIM LAURIER

NEW VANGUARD 283

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AMERICAN GUIDED MISSILES OF WORLD WAR II

INTRODUCTION

The development of guided missiles by the US armed forces in World War II was cloaked in secrecy for many years. The US Navy and US Army Air Forces developed a surprisingly wide array of guided weapons including bombardment missiles, guided bombs, and anti-ship missiles. Many of these programs proved to be on the bleeding edge of technology and far beyond the state-of-the-art in 1941–45. Nevertheless, the story of US guided weapons in World War II helps to illuminate the birth of the missile age.

CRUISE MISSILES

The Aerial Torpedo

The roots of American missile development can be traced back to efforts in World War I to develop "aerial torpedoes" guided by simple gyro-based autopilots or radio control. The Navy initiated a project in April 1917, consisting of Elmer Sperry's gyro system mounted in a small Glenn Curtiss bi-plane carrying a half-ton warhead up to fifty miles. After witnessing one of the Navy tests, the US Army Signal Corps started its Liberty Eagle aerial torpedo program with a team consisting of Charles Kettering for the flight controls, Childe Wills of the Ford Motor Company for the engine, and Orville Wright for the airframe. Better known as the Kettering Bug, flight tests began in September 1918. These programs fell victim to immature guidance technology and a lack of funding after the war.

The Kettering Bug was the Army's 1917–18 attempt to develop a cruise missile. However, the guidance technology of the day was far too immature for a functional weapon. This example is preserved at the National Museum of the US Air Force at Wright Patterson AFB. (Author)

Gen. Henry "Hap" Arnold's early connection with the Kettering Bug was the most tangible link between the World War I and World War II missile programs. In 1936, he was appointed assistant Chief of the Air Corps. A remotely-piloted aircraft was tested in 1938, leading to the revival of the aerial torpedo concept in August 1938. After Arnold became Chief of the Air Corps in September 1938, he outlined the requirements: a range of at least 20 miles, sufficient accuracy to strike a target

two miles square such as a military base or factory, and a warhead of at least 200lb. Vega Airplane Company proposed using its Model 40 target drone as the basis of the system. Kettering, at the time the manager of the Research Laboratories Division of General Motors in Detroit, suggested a more ambitious design. Arnold subsequently changed the requirements in January 1940, extending the range to at least 100 miles and improving the accuracy to a half square mile. Although the aerial torpedo would rely on a gyroscope-based flight control system, this would be supplemented by radio control either from an accompanying control aircraft or from the ground.

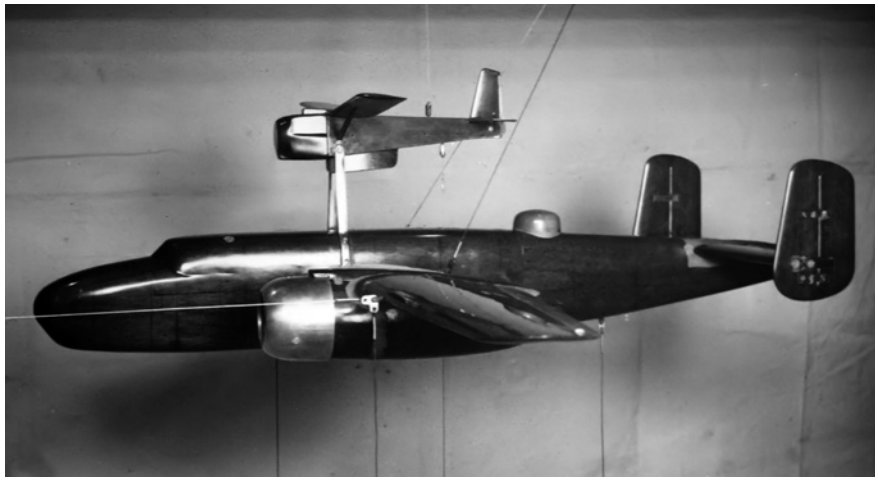
The General Motors Aerial Torpedo was a revival of Kettering's World War I Bug. This is No. 12 from the second batch of five prototypes that were redesigned to include a television camera in the bathtub below the fuselage.

The War Department signed a contract for the first ten "controlled-bombs, power-driven" from General Motors on February 18, 1941. The project internally was called the GM A-1 or MX-53 (Materiel Experimental) by the AAF Materiel Center at Wright Field, Ohio, though it was commonly known as the Bug after its World War I ancestor. During these formative years of missile technology, there was considerable interplay between the development of radio-controlled target drones and early radio-controlled missiles. The GM A-1 used the same radio-control system as the Culver PQ-8 target drone.

Flight tests of Kettering's new design began at Muroc Dry Lake in California. The initial flights were plagued with crashes, but the fourth flight on December 8, 1941 lasted for 1 hour and 35 minutes. Based on the tests, an improved batch of five GM A-1s was ordered in July 1942. The second batch was fitted with an RCA SCR-549 Block 1 television camera/transmitter to permit the operator to monitor the course of the flight. Of the 15 A-1 powered-bomb prototypes built by General Motors, 12 were destroyed during tests by early 1943. An AAF study concluded that at least a hundred more units would have to be built and tested before the design was satisfactory for serial production, requiring at least another year of development. By this time, it was recognized that the GM A-1 powered bomb was too small and too slow with a speed of only 200mph. As a result, the program was terminated in August 1943.

In the meantime, the AAF had begun to consider much larger powered-bombs by adding radio-control systems and auto-pilots to full-size aircraft. In 1942, the AAF selected two competitors. Fleetwings built two related aircraft, the XBQ-1A and the XBQ-2A, that were essentially identical except for their engines. Like most large powered-bombs, they were "optionally piloted," meaning that they had a cockpit installed for routine flight tests. The first and only XBQ-1A was delivered in May 1944 and crashed on its first flight. The XBQ-2A was flown successfully, but the AAF decided that it was too costly as an expendable weapon. The Fairchild entry was the XB-3A, essentially a remotely-piloted version of the existing AT-21 Gunner advanced gunnery trainer. The first of two XB-3As was not delivered until July 1944. As will be discussed in more detail below, by this date, the AAF had switched to the idea of expending old bombers for this mission instead of buying custom-built controlled bombs.

Had the GM AT-1 reached production, the plan was to air-launch it from medium bombers. Due to its size, it was necessary to mount the GM AT-1 on an overhead pylon, as seen in this wind tunnel model on a B-25.



The Navy was also pursuing a very similar program and in April 1943, the AAF requested the loan of two of the Navy's assault drones. An Interstate TDR-1 assault drone was tested by the AAF as the XBQ-4. However, nothing came of these trials, nor of other AAF projects to test other Navy assault drones.

Project Castor: Weary Willies

The idea of converting existing aircraft into power-driven controlled bombs began in January 1944 at the Special Weapons Branch of the Equipment Lab at Wright Field, Ohio. The initial concept was to use the C-47 transport aircraft or assault gliders, carrying ten tons of high explosives. The Materiel Command of the USAAF Engineering Division broadened the concept to include a variety of bombers, including the B-24 and B-17. The program formally began on March 25, 1944 with preparations for twelve conversion kits. The guidance system was based around the aircraft's autopilot. A two-man crew would pilot the aircraft during the initial phase, and once cruising altitude was reached, activate the autopilot and bail out. An accompanying control aircraft would then steer the aircraft to target using a radio-control system. The aircraft would be stripped of any extraneous weight, including gun turrets. The program received enthusiastic encouragement from the combat theater. In May 1944, Lt. Gen. James Doolittle, the 8th Air Force commander, offered the use of worn-out "Weary Willie" bombers available in Britain as the basis for flying bombs.

After rejecting the GM AT-1, the AAF began to explore the possible use of larger aircraft that would not require launching from a parent aircraft. One of the contenders was the Fleetwings XBQ-2A seen here in 1944. Like the other contenders, it was an optionally-piloted aircraft with a normal cockpit for routine flight trials.

On June 9, 1944, the B-17F and B-24J were selected as the first missile planes, now labeled as the RB-17F and RB-24J. Besides the dozen missile planes, two B-17s, one B-24, and one P-38J "Droopsnoot" were selected as the control aircraft. On June 19, the project received the codename MX-541 Castor.

The priority for Project Castor increased dramatically on June 20,

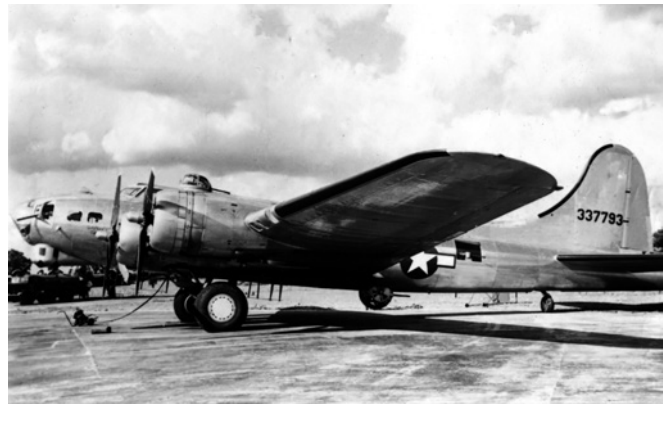
1944 when Maj. Gen. Alfred Maxwell, Director of Operations of the US Strategic Air Forces in Europe (USSTAFE), telegraphed an urgent request that the Materiel Command dispatch any available experimental guided weapons to Britain with highest air priority. The Luftwaffe had initiated Operation *Eisbär* (*Polar Bear*) earlier in June, launching the new V-1 cruise missile against London.* The USSTAFE commander, Lt. Gen. Carl Spaatz, was under intense political pressure to destroy the launch sites, especially the large "Heavy Crossbow" bunker launch sites that were impervious to conventional bomber attacks. The requirement was to attack the bunkers with a very heavy load of explosives within ten to twenty feet of the aim point.

"Gremlin Gus II" was one of the original ten B-17s converted for Project Aphrodite using the Double Azon guidance system. This required the addition of two rows of AN-117-A antennae on the nose in front of the cockpit for the Azon system AN/ARW-1 radio receiver. (USAAF via Frank Law/ Burtonwood Association)

Some preliminary studies had suggested that the radio-control system in use with the Azon guided bombs could be adapted for this requirement. The Azon is described in more detail below. Since the Azon only controlled the bomb along one axis, two systems were combined, one to control altitude and one to control direction. A crash program began under the codename Aphrodite with the 8th Air Force Operational Engineering Section at Bovingdon overseeing the program. Development of the Double Azon was undertaken by the 8th Air Force's principal Azon expert, Maj. Henry "Jim" Rand. The radio link between the "Mother" and "Baby" consisted of the AN/ARW-18 transmitter on the control aircraft and the AN/ARW-1 receiver on the missile.

An experimental B-17F "robot" and "mother" ship were completed on June 23, and conducted the first test flight on the evening of June 24. The USSTAFE Base Air Depot 1 at RAF Burtonwood was assigned the conversion program and through the end of June, a total of ten "Babies" were converted, numbered B1 to B10. On July 8, Spaatz ordered the conversion of 65 Aphrodite aircraft, with three-quarters of them loaded with 10 tons of nitrostarch high-explosive and the remainder with jellied gasoline (napalm).

The first Aphrodite mission was conducted on August 4, 1944 using four Babies. Robot B1, targeting the Watten missile bunker, aborted the first pass due to cloud cover, but reached the objective on its second pass. The B-24 Mother was unable to activate the "Down" control, so Robot B1 was flown back out toward the English Channel. It was hit by flak and exploded before it could be reoriented for another pass. Robot B4 aimed at Wizernes operated satisfactorily, but cloud cover momentarily obscured the target during the final approach and the B-17 impacted about 700 yards beyond the bunker. On approach to the Mimoyecques bunker, the B-17 Mother crew felt that Robot B5 was flying too high and tried to reduce its altitude to the standard 300 feet. The controls were very crude, and as a result, it impacted about 1,500 feet short of the



B-17G (43-37793) was one of two bombers that were assigned to the 388th Bomb Group as an Azon Mother for Project Aphrodite. The three AN-117-A antenna for the AN/ARW-18 radio transmitter for the Azon system can be seen below the belly of the aircraft. (USAAF via Frank Law/ Burtonwood Association)

* Steven J. Zaloga, *Operation Crossbow 1944*, Osprey Air Campaign 5: 2018.

target. Robot B8, intended for Siracourt, experienced an altimeter failure over England. One crewman parachuted safely, but the aircraft suffered a series of uncontrolled climbs, finally stalling and crashing near Woodbridge in Suffolk.

Mission 2 was conducted on August 6 using B-17F "Franklin Yellow" filled with 10 tons of Torpex explosive and B-17G "Franklin White" filled with 830 gallons of jellied gasoline and a dozen 100lb bombs. The Franklin Yellow group encountered a formation of B-24 bombers over the English Channel, which led to the Mother overshooting the Baby and experiencing control problems. Franklin Yellow went out of control, turned sharply to the left, flipped over on its back, and crashed into the sea. Franklin White seemed to be flying properly when the crew bailed out, but moments later the Mother noted that the B-17G was drifting to the right. This situation grew progressively worse with the Baby starting to do complete turns. After failed attempts to bring Franklin White under control using the second Mother, the B-17 was deliberately crashed into the sea rather than risk it inadvertently flying back to England.

Project Anvil

The US Navy offered to assist Aphrodite by adapting its remote-control technology to the PB4Y-1 Privateer, the maritime patrol bomber version of the B-24 Liberator bomber. This remote-control system was significantly more sophisticated than the crude Double Azon. The Anvil was fitted with two television cameras, one in the cockpit to monitor the flight instruments and the other in the nose to aim the robot into the target. The Project Anvil conversions were undertaken at the Naval Air Factory in Philadelphia, and the first Anvil PB4Y-1 and two modified PV-1 Ventura motherships left the United States on July 7, 1944. The Anvil PB4Y-1 was dispatched on its Aphrodite mission on August 12, aimed for the Mimoyecques bunker. The formation became airborne as planned, but before the crew could bail out, the 10½ ton load of Torpex prematurely detonated, obliterating the Anvil PB4Y-1 south of Halesworth and causing extensive damage on the ground

The Naval Aircraft Factory in Philadelphia converted two PB4Y-1 Privateer patrol bombers into the Anvil guided bombs for Project Aphrodite missions. No photos of these aircraft have ever been located. This illustration of Kennedy's ill-fated aircraft shows the configuration of the conversion based on existing illustrations and documents. (Author)

below. The pilot of the aircraft was Lt. Joseph P. Kennedy, son of the former US ambassador to Britain, and elder brother of future US president John F. Kennedy. Further Aphrodite missions were halted to determine the cause of the accident. A faulty safe-and-arming system was considered the most likely cause, a conclusion verified by more recent research.

Operation *Crossbow*, the campaign against the German V-1 sites, came to a close by the end of August 1944 as Allied troops overran the missile launch sites in France and Belgium. As a result, the targets for the remaining missiles shifted to other high-value, heavily protected targets. The explosive-laden bombers were very vulnerable to enemy fighters, so most missions were conducted against coastal targets. Deep-penetration missions into Germany were judged too dangerous. A second Anvil Privateer was expended at the Kriegsmarine base at Heligoland on September 3, 1944, striking an area with fuel dumps and barracks on Dune Island. This was the first successful mission of the Aphrodite program.

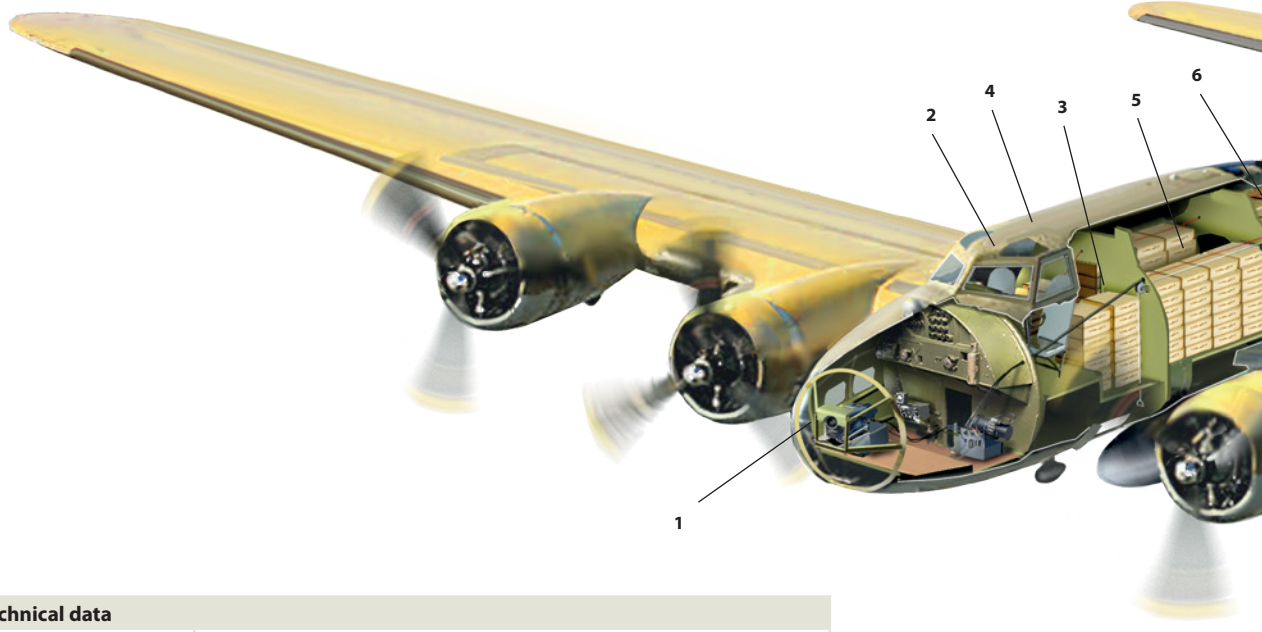
AAF Aphrodite Missions

Type	Number	Name/Unit Code	Number	Mission Date	Target
B-17F-100-BO	42-30342	T'aint-a-Bird/BG-B	B1	4 August 1944	Watten
B-17F-65-DL	42-3461	-/PY-S	B4	4 August 1944	Wizernes
B-17F-27-BO	41-24639	Careful Virgin/OR-W	B5	4 August 1944	Mimoyecques
B-17G-1-VE	42-39835	Wannta-Spar/TU-N	B8	4 August 1944	Siracourt
B-17G-15-BO	42-31394	Franklin White	Robot 1	6 August 1944	Watten
B-17F-90-BO	42-30212	Quarterback/Franklin Yellow	Robot 2	6 August 1944	Watten

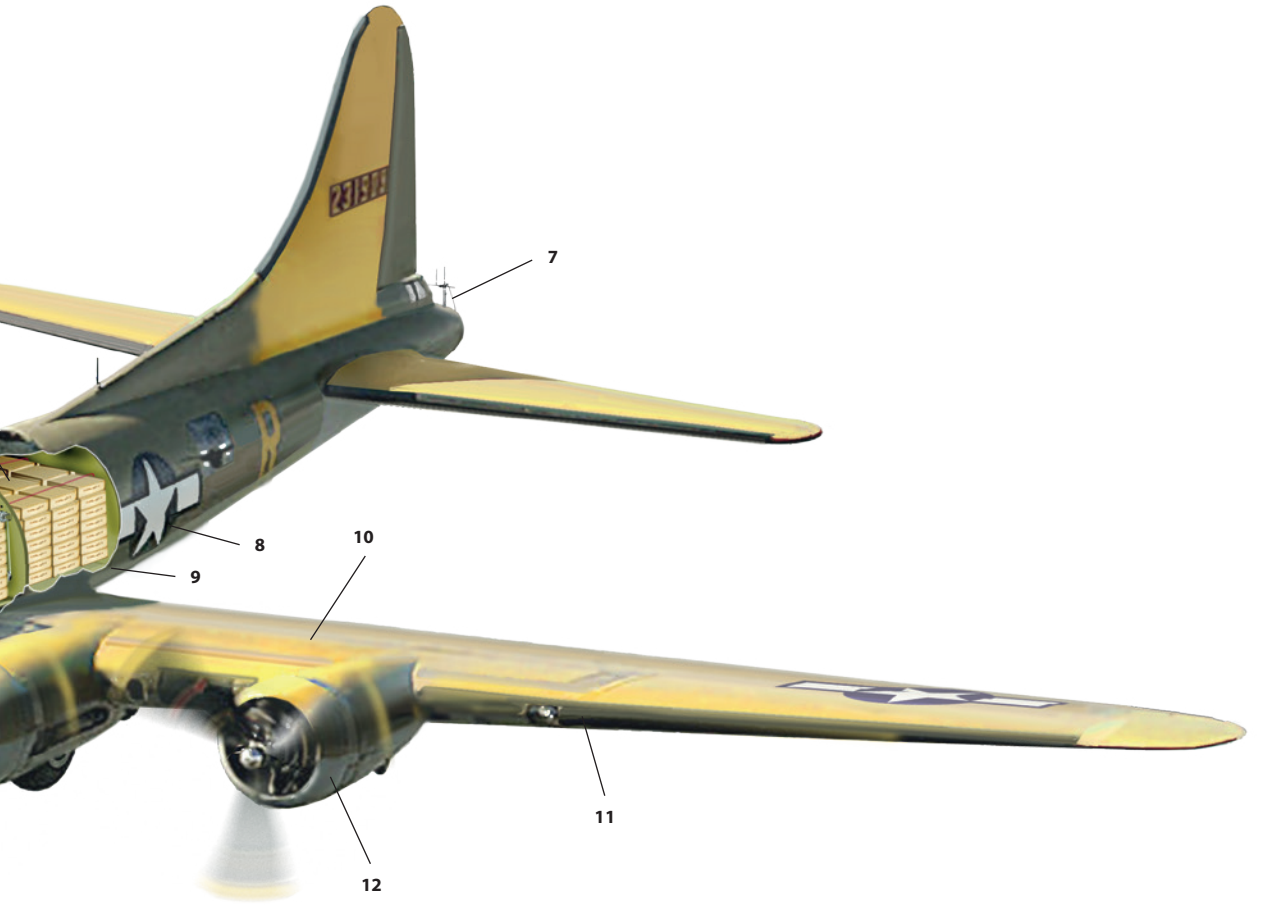
While the improvised Aphrodite program was underway in Britain, the Castor Project continued in the United States. On July 5, plans were approved to convert 500 missiles and 100 control aircraft. The first RB-17G and RB-24J were sent for conversion into Castor aircraft on July 12. On August 5, 1944, the Castor designations were changed with the missiles designated as BQB-17F and BQB-24J, and the control aircraft as CQB-17G, CQB-24J, and CPQ-38. This was changed again on August 25 when the missiles were given assault drone designations as the BQ-7 for B-17 conversions and BQ-8 for B-24 conversions.

The Castor aircraft used a flight control system closer to the Navy's Anvil than to the Aphrodite's Double Azon. The Castor system included two SCR-549A Block III television cameras, one in the cockpit to monitor the flight instruments and one in the nose to help aim the aircraft during the terminal phase. The Castor Baby aircraft were fitted with a small AN-145 or AN-146 antenna at the rear instead of the triple AN-117-A antenna array fitted on the Azon aircraft. The aircraft received a set of remote-controlled servos to operate the various flight aircraft controls including the throttle, propellers, landing gear, and cowl flaps. The Castor conversions also included an AN/TPN-1 Eureka navigation beacon that could be tracked by the AN/APN-2 Rebecca navigation aid on the control aircraft to monitor the drone even in cloudy conditions. To further aid the control aircraft, the BQ-7 was fitted with a smoke generator pod under the fuselage that emitted a white smoke trail.

The first Castor BQ-7 detachment from Wright Field arrived in Britain on August 2, 1944. At RAF Burtonwood, twelve B-17 bombers were converted into BQ-7 drones as well as five CQB-17G motherships. The first drone



Technical data	
Base aircraft	B-17G heavy bomber
Temporary crew	Pilot, flight engineer (bale out after take-off)
Length	74 ft 4 in
Wingspan	103 ft 9 in
Powerplant	4 × Wright R-1820-97 "Cyclone" 1,200hp radial engines
Maximum speed	285mph
Cruising Altitude	20,000 ft
Loaded weight	63,200lb
Explosive type	Torpex (41.8% RDX, 40.2% TNT, 18% aluminum powder)
Explosive weight	18,425lb Torpex (21,105lb inc. packing)
Fuzing	Modified M100 series fuzes, M115 adapter booster
Television cameras	Two AN/SCR-549 Block 3
TV transmitter	AN/AXT-2
Radio altimeter	AN/APN-1
Navigation	Minneapolis-Honeywell C-1 autopilot
Control radio transmitter	RC-65 (AN/ARW-18) transmitter (on CQB-17 Mother)
Control radio receiver	RC-64 (AN/ARW-1) receiver (on BQ-7 Baby)
Navigation aid	AN/TPN-1 Eureka (APN-2 Rebecca in Mother)
RC radio receiver	BC-617-T2
Radar beacon	AN/APN-7, AN/APX-14 Black Maria, or AN/APN-21
IFF equipment	AN/SCR-729



Key

1. RCA SCR-549 Block 3 TV camera for guidance
2. RCA SCR-549 Block 3 TV for monitoring instruments
3. 25 boxes of Torpex (1,575lb) in pilot's compartment
4. Top turret removed
5. 210 boxes of Torpex (13,230lb) in bomb-bay
6. 100 boxes of Torpex (6,300lb) in radio room
7. AN-145 or AN-146 TV transmitting antenna
8. Underbelly ball turret removed
9. Smoke tank under fuselage (not visible)
10. Upper surfaces painted chrome yellow for visibility
11. De-icing boot
12. Wright R-1820-97 "Cyclone" radial engine

conversion was completed on August 20 and the first Castor mission was conducted on September 11 against the Heligoland submarine pens. Of the ten Castor missions conducted through January 1945, only one was marginally successful. Flak, equipment failure, and poor weather plagued the program.

Castor BQ-7s Expended in the ETO (European Theater of Operations)

Type	Number	Mission	Target
B-17F-90-BO	42-30180	11 September 1944	Heligoland
B-17F-100-BO	42-30363	14 September 1944	Henningstadt
B-17G-1-VE	42-39827	14 September 1944	Henningstadt
B-17F-85-BO	42-30039	15 October 1944	Heligoland
B-17G-10-DL	42-37743	15 October 1944	Heligoland
B-17F-60-DL	42-3438	31 October 1944	Heligoland
B-17F-85-BO	42-30066	31 October 1944	Heligoland
B-17F-100-BO	42-30353	5 December 1944	Herford
B-17G-1-VE	42-39824	5 December 1944	Herford
B-17F-90-BO	42-30178	1 January 1945	Oldenburg
B-17F-95-BO	42-30237	1 January 1945	Oldenburg

One special Castor mission was a plan to attack the German battleship *Tirpitz* in the Alten Fjord in Norway. Since normal high explosive would not be sufficient, British munition experts recommended a large hydrostatic bomb, detonated underwater. These large weapons could not be loaded into the bomb-bay of the B-17, so Boeing engineers outlined a method to remove the fairing behind the B-17 cockpit. This created an opening large enough to allow the weapons to be lowered into the fuselage from overhead. Only one aircraft was converted in this fashion, Aphrodite B3 "Gremlin Gus II." After the payload was secured into the fuselage, the opening was faired over with sheet metal, leading to the drone's new nickname "The Roadster." In the event, the *Tirpitz* was sunk on November 12, 1944 by RAF Lancaster bombers using Tallboy penetrating bombs.

"Gremlin Gus II" was later upgraded to a BQ-7 with Castor guidance equipment. It was assigned to a mission against the German battleship *Tirpitz* that required the insertion of a massive hydrobomb through an overhead opening in the fuselage. It was subsequently renamed "The Roadster" in this configuration. In the event, its mission was canceled. (USAAF via Frank Law/ Burtonwood Association)

The Oldenburg mission on New Year's Day 1945 was the last Castor mission in Europe. By this stage, the 8th Air Force felt that the system was not effective under poor winter weather conditions and against targets heavily defended by flak.

Since the existing nicknames for the program were so obvious, on November 29, 1944, new codenames were adopted, as shown below.

Old codename	New codename
Willie/Castor	Abusive
Mother	Bluefish
Baby	Corticated
Orphan	Cottongrass

By late 1944, a new plan was underway to permit BQ-7s to attack battlefield targets using the SCR-584 radar for monitoring the flight with the terminal phase controlled by ground-based forward observers. The plan was to deploy the BQ-7/BQ-8s in Europe with the Phase A "Orphan" ground control system starting in February 1945. The anticipated expenditure rate was about twenty-five BQ-7s a month. However, the first tests of the ground-control system were delayed until January 13, 1945 using a B-17F/BQ-7 and on January 19 with a B-24/BQ-8. Procurement of equipment was severely cut back on April 6, 1945, due to the likelihood that the war in Europe would soon be over.

In spite of the difficulties and poor performance of the Aphrodite/Anvil/Castor drones in Europe, there was some optimism about their potential use in the Pacific, where weather conditions were more favorable and the flak less intense. In October 1944, work began on conversion of B-29 bombers into Mothers to permit very long-range missions using the BQ-8 drones. Development work on Project Abusive continued to satisfy potential requirements in the Pacific. Some consideration was also given to the conversion of smaller fighter aircraft into missiles using the Castor/Abusive technology. In the event, the war ended before any of these systems were deployed to the Pacific. Curiously enough, in 1946 the Air Force began work on remotely-piloted B-29 bombers armed with a nuclear bomb as the MX-767 Banshee.

The Naval Air Factory TDN-1 assault drone was used for training off the small carrier USS *Sable* on the Great Lakes in the summer of 1943.

Navy Assault Drone Programs

During the 1930s, the Royal Navy began using the DH 82B Queen Bee as target drones for naval anti-aircraft gunnery training. In 1935, the US Navy's Chief of Naval Operations, Adm. William Standley, saw a demonstration of these while visiting Britain. On his return, he instructed the Naval Research Laboratory's Radio Division to begin work on an American counterpart. This effort was led by Lt. Com. Delmar S. Fahrney, who coined the term "Drone" in honor of its inspiration, the "Queen Bee."

The Radio Division began conducting a series of tests of NOLO (No Live Operator)

The Interstate TDR-1 assault drone was an optionally-piloted aircraft with a simplified cockpit to enable the aircraft to be flown by a pilot during routine assignments.

aircraft. These were ordinary biplane training aircraft that operated in pairs. One aircraft was fitted with automated controls to operate the control surfaces and throttle, while the "mothership" contained a radio operator to steer the NOLO aircraft for anti-aircraft gun training. Fahrney suggested that drones could be used in a combat role as well. The first test using a radio-controlled Curtiss N2C-2 drone was conducted against the old battleship USS *Utah* on September 14, 1938, proving the viability of the concept. Project Fox examined the use of an assault drone to launch a torpedo or drop a bomb on the target, or alternately crash the drone into the target as a missile.

The most important breakthrough in assault drones was RCA's development of a lightweight television camera with transmitter. Weighing 70lb, this might seem an enormous contraption by today's standards, but in 1940, it was cutting-edge technology. The first flight tests of the Project Fox aircraft fitted with the RCA camera were conducted in February 1941. In August 1941, a series of flight tests was conducted and a mock target was hit 47 out of 50 times.

In spite of these successes, the Chief of the Bureau of Aeronautics, Rear Adm. John Towers, was unenthusiastic about diverting aircraft production to such futuristic concepts. This changed after the Pearl Harbor attack in December 1941, when the Navy was more receptive to unorthodox ideas. In May 1942, the Chief of Naval Operations, Adm. Ernest King, gave his blessing to the development of an assault drone "at the earliest practicable date." There were some suggestions that obsolete Devastator torpedo bombers should be used. Naval aviators were loath to use any aircraft in such a role, since combat aircraft, even obsolete ones, were in such short supply. Towers warned Fahrney that even with King's support, he did not want the drones to divert resources from Navy aircraft programs. The assault drone program was given the codename Operation *Option*.

Knowing that Towers would block any attempts to have the drones built by major aviation firms such as Grumman, Fahrney turned to smaller

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Interstate TDR-1 "Dog" Assault Drone, STAG-1, Green Island, South Pacific, October 1944

The TDR-1 assault drone was codenamed the "Dog" by its STAG-1 crews, based on the earlier Project Dog. They were factory finished in a scheme of dark sea blue over white, with the undersurface color lapping up over the leading edge of the control surfaces. STAG-1 later recommended that this practice end and that the leading edges should be painted blue. A three-digit serial number was applied to the tail. STAG-1 named most of their Dogs, in this case, "Available Jones," a character from the *Li'l Abner* comic strip. This particular drone was expended during the attacks on Japanese anti-aircraft batteries on Ballale-Poporang in the Solomons on October 1, 1944, armed with a single 2,000lb general-purpose bomb. The TDR-1 was 36 feet 4 inches in length with a 48-foot wingspan. It had a gross weight of 10,000lb, a range of 890–1,400 miles and a speed of 225mph.

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organizations starting with the Naval Aircraft Factory in Philadelphia. The assault drones used simple and inexpensive plywood construction with low-power engines, since the more powerful engines were earmarked for combat aircraft and trainers. The first of the designs was the TDN-1. The "TDN" stood for Torpedo Drone N, the "N" being the code letter for the Naval Aircraft Factory. To simplify transport of these aircraft, they were configured as optionally-piloted aircraft. They included an elementary cockpit with simple flight controls, but for combat missions the canopy could be removed. The TDN-1 design proved too complicated and expensive for mass production. After building about a hundred TDN-1 drones for testing and training, the next generation was developed by Interstate Engineering.

The Interstate Engineering TDR-1 had a cruising speed of 125mph and 150mph in a terminal dive. The TDR-1 assault drones could be operated in one of two fashions. As expendable missiles, they could be steered directly into their targets with a single 2,000lb bomb or four 500lb bombs as their payload, or they could be operated as remotely-controlled bombers attacking multiple targets with a mixture of 100lb and 500lb bombs. In the bomber mode, they could return to base and land. The Grumman TBM-1C Avenger was modified as the control ship for the drones. A large, retractable dome was added under the rear fuselage to house a rotating surface-search radar codenamed "Roger."

The original scheme for Operation *Option* was remarkably bold. The plan called for the formation of 18 assault drone squadrons with 162 drone control aircraft and 1,000 drones, along with 1,300 aircrew and 10,000 support personnel. The total cost of the program was pegged at $235 million, which would be about $3.3 billion today. By March 1943, the objectives had been trimmed back to three squadrons with 99 drone control planes, 891 drones, and 3,650 personnel. In the summer of 1943, the Navy established three Special Task Air Groups (STAG) to operate the assault drones. After initial crew training, STAG-1 began training flights aboard the training carriers USS *Sable* and USS *Wolverine* on Lake Michigan.

While training was underway, Capt. Oscar Smith, one of the officers on Adm. King's staff responsible for Operation *Option*, headed to Hawaii. His assignment was to coordinate future drone operations with the Pacific theater commander, Adm. Chester Nimitz. Up to this point, no one had informed Nimitz or his staff of the top-secret Operation *Option*. By September 1943, Nimitz was content with conventional piloted aircraft and not especially interested in futuristic and potentially troublesome substitutes. He sent a message to Adm. King in Washington that "While deeply interested in the development of new weapons of this type, we lack carriers, landing fields, and other facilities to try out these unproven weapons." Accepting the drones for use in the Central Pacific would mean assigning one or more aircraft carriers to their operation, and there were never enough aircraft carriers.

After being turned down by Nimitz in September 1943, Smith turned to the South Pacific commander, Adm. "Bull" Halsey. Halsey's air commander, Rear Adm. E.L. Gunther, showed more sympathy for the scheme, since there was a number of isolated Japanese garrisons that would make suitable targets. Adm. King reviewed Nimitz's objections to Pacific deployment and overruled him, and on February 24, 1944 ordered that "experience with the STAG-1 drones must be gained methodically but without delay." A Special Air Task Force (SATFOR) was approved in March 1944. The original plan

A STAG-1 ground crew arms an Interstate TDR-1 "Dog" named "Edna III" prior to a mission from Sunlight Field on Banika Island. In this view, the nosecone has been removed in order to service the RCA television camera.

was to use STAG-1 in support of the amphibious landings on Eniwetok. However, the Eniwetok landings concluded in February 1944 before STAG-1 was ready.

STAG-1 arrived in the Russell Islands in early June 1944 and was based at Sunlight Field on Banika Island near Guadalcanal. The first remote-control take-off by one of the squadron's TDR-1 drones took place on June 26, 1944. STAG-1 flew 96 training flights before its first combat mission. The early television cameras did not have good resolution, and they needed a well-lit target with good contrast between the target and the background. The first target selected was the abandoned Japanese transport ship *Yamazuki Maru*, beached off Cape Esperance on Guadalcanal. The attack took place on July 30, 1944 using four TDR-1 assault drones. Two of the drones impacted the ship and the other two were near misses. The results were favorable enough that approval was given to begin actual combat missions against Japanese targets in the Bougainville-Rabaul theater, with STAG-1 operating from forward airfields on Green Island and Sterling Island.

STAG-1 began combat missions on September 27, 1944 with an attack on a beached Japanese transport ship off the south shore of Bougainville, striking it with two of four drones. The first attack on an active Japanese target was the mission of October 1, 1944 against Japanese anti-aircraft positions on Ballale and Peperang Islands. A total of eight drones dove into the targets, several of the drones being seen to strike in the midst of the Japanese batteries. The mission on October 5 was more challenging, a series of caves near Karavia Bay on Rabaul were used to protect supplies from conventional air attack. Two of the drones were ineffective due to apparent Japanese radio interference with the control signals. Of the remaining two drones, one struck the cave entrances and one missed. A bridge in Simpson Harbor, Rabaul was the target on October 9. Japanese anti-aircraft fire hit two of the drones during their approach, one drone crashed due to equipment failure, and one drone detonated about a thousand feet from the bridge. The TDR-1's slow speed made it very vulnerable to Japanese anti-aircraft fire.

The final mission of STAG-1 was conducted on October 27. In total, 50 drones were used on combat missions, of which 31 hit or damaged their

The Northrop JB-1 Bat was a futuristic flying wing design with two teardrop-shaped pods in the wing root to carry a pair of 2,000lb bombs. It had a wingspan of 28 feet.

targets, 3 were shot down by anti-aircraft fire, and 15 were lost due to mechanical or electronic failures. Navy enthusiasm for the assault drones was waning. The TDR-1 was judged to be too slow and too short-ranged for the Pacific theater, and the Navy had no interest in operating an unreliable flying bomb with a one-ton warhead from the deck of an aircraft carrier. In March 1944, the Navy decided to halt further assault drone production at 388 aircraft. STAG-2, intended for the ETO, was disbanded before going into combat. Following the last October 1944 Rabaul missions in the Pacific, the drone squadrons were retired.

Jet Bombardment Missiles

One of the acknowledged problems with the early strike missiles was their slow speed. With the gradual maturation of jet propulsion during the war, more interest turned to the potential use of jet- or rocket-powered assault drones. A March 1943 Bureau of Aeronautics (BuAer) study proposed several Navy jet-powered assault drones. Interstate was selected to design a flying-wing assault drone designated the XBDR-1. Although portions of a full-scale mock-up were completed in 1944, no flying prototype was built.

When the Luftwaffe began bombarding London with the V-1 cruise missile on June 13, 1944, the AAF began to examine the development of a comparable weapon for area bombardment. On July 5, 1944, Northrop was contracted under Project MX-543 to develop a jet flying bomb, patterned on their P-79 flying-wing fighter powered by two GE BI-5 turbojet engines. The missile included two tear-dropped containers at the wing roots to carry two 2,000lb bombs, double the warhead of the German V-1. The MX-543 was expected to have a range of 200 miles, a cruising altitude of 15,000 feet and a speed of 350 to 450mph. Designated as JB-1 (Jet Bomb-1), Northrop delivered thirteen wing sets and two center sections by November 1944. The first JB-1 missile was launched at Eglin Field's Santa Rosa Island on December 7, but quickly stalled and fell into the water about 500 yards from the ramp. The GE turbojets offered only about half their intended 400lb thrust, leading to the decision on February 19, 1945 to substitute the Ford PJ-31-1 pulse-jet developed for an American V-1 copy. This modified version was designated as JB-10 and used up the remaining components from the JB-1 contract.

A JB-2 missile on the launch ramp at Eglin Field on November 11, 1944. Since the AAF did not know the configuration of the German launch ramp, it originally used a rocket sled instead of the German steam catapult method.

In parallel to Project MX-543, the AAF initiated MX-544, a direct copy of the German V-1 cruise missile. With British cooperation, a large number of V-1 components was collected and shipped back to the United States,

arriving on July 13, 1944. Republic Aviation in Farmingdale, New York was selected as the prime contractor, with Ford serving as contractor for the PJ-31-1 pulse-jet engine and Jack & Heintz in Cleveland, Ohio for the flight control system. Engine testing began on August 1, and the first production missile underwent ground-tests at Republic on September 8, a remarkable seven weeks after the start of the program.

Launching the missile proved to be a bigger challenge than copying and building it. Although it was known that the V-1 was launched from some sort of long rail, details of the German launcher were a mystery at the start of the program. The first US launches used a 2,000-foot launch track at Muroc Dry Lake with a rocket sled until more compact launchers were ready. The first test launch was conducted on October 12, 1944; it flew only 2 miles before crashing. There were several more failed test launches until the first successful flight on November 10. Many more test flights were conducted to overcome a host of technical problems. Samples of the German Walter catapult launcher were captured in September 1944 and later tested in the United States. Aside from improved ground launchers, the AAF began preliminary studies to air launch the JB-2, with the first test from a B-17 bomber on March 2, 1945.

A total of 77 missiles were delivered up to January 13, 1945 with plans to increase this to at least 1,000 a month. One of the most significant improvements was the introduction of radio-transceivers on the missiles. This enabled the missiles to be tracked using an SCR-584 radar, with mid-course corrections sent to the missile in flight by radio to increase its accuracy.

On January 12, 1945, Gen. Hap Arnold established ambitious production requirements. The aim was to have the capacity to launch 500 per day by February 1946 with an authorization to procure a total of 75,000 missiles. Arnold's orders soon ran into production realities. A study in late January 1945 indicated that the JB-2 program would absorb up to 25 percent of shipping bound for the ETO and cost over $1 billion. After consulting the

The USAAF planned to use the JB-2 Thunderbug against Japan from bombers. Tests continued after the war, including this example from a B-29 at Eglin Field in August 1950.

BELOW LEFT
The Navy referred to its version of the JB-2 as the KGW-1 Loon. This example is preserved at the Udvar-Hazy Center at the US National Air and Space Museum in Chantilly, Virginia. (Author)

BELOW RIGHT
The Northrop JB-10 was an attempt to redeem its flying wing design by substituting the JB-2's Ford PJ-31-1 pulse-jet for the GE turbojet. It had a wingspan of 29 feet, a cruising speed of 425mph and a range of 185 miles.

The JB-4 was developed as a smaller alternative to the JB-2, based on the GB-4 fuselage with its 1,000lb warhead.

Air Materiel Command, the War Department reduced the total order to 10,000 missiles.

When the war in Europe ended in May 1945, the focus shifted to the missiles' use against Japan. Both the AAF and Navy planned extensive use of the JB-2 in the preparatory bombardment of Japan prior to any amphibious landings. The AAF planned to use various bombers including the B-24 and B-29. The US Navy began to examine a variety of potential naval platforms, including the LST (Landing Ship Tank) and escort carriers, as well as aircraft such as the PB4Y-2 Privateer.

The first Navy contract for these missiles was issued on February 1, 1945 and the first delivered in March. The Navy designated their JB-2 missiles as the KGW-1 Loon. In May 1945, the new test range at Point Mugu was assigned for Loon tests. An escort carrier was dispatched to Point Mugu in August 1945 to begin training. The Navy contracted the McKiernan-Terry Company to develop the XM-1 catapult launcher for launches from escort carriers and the first arrived at Point Mugu in August 1945. The first powered launch of a Navy Loon from the XM-1 catapult took place at Point Mugu on January 7, 1946, but it ended prematurely due to engine failure. A total of 43 Loon launches were conducted over a year, with most failing at some point due to a variety of technical problems. The first fully successful catapult flight was undertaken with missile No. 38 on November 5, 1946.

The end of the war with Japan in August 1945 led to an abrupt cancellation of further JB-2 production on September 15, 1945, with a final total of 1,391 missiles. Although the JB-2/KGW-1 Loon never saw combat, it became an important stepping stone to post-war American cruise missile design, including the Air Force Matador and the Navy Regulus cruise missiles.

There were several attempts to build alternatives to the JB-2. As mentioned before, Northrop had shifted from its original turbojet JB-1 to the JB-10, powered by the same Ford pulse-jet as the JB-2. The first test launch at Eglin Field, Florida on April 6, 1945 was unsuccessful. The subsequent tests had mixed results with the longest range reached being 30 miles. Since the JB-2 was already successful and in mass production, JB-10 was formally canceled at the end of January 1946.

The Air Force also developed the JB-4 under Project MX-607 as a cheaper alternative to the JB-2. This used the airframe and flight controls of the GB-4 glide bomb, but was fitted with a pulse-jet engine. Instead of using a 2,000lb bomb, it was fitted with a lighter 1,000lb warhead in order to provide more

The Navy considered developing the Gorgon as a jet bombardment missile as the KUN-1 Gorgon IIC, seen here during engine tests at NAMU in Johnsville, Pennsylvania in December 1946. The missile was 18 feet long with an 11-foot wingspan. It weighed 1,690lb and was armed with a 1,000lb M65 bomb. It had a maximum speed of 450mph and an effective range of 70–100 miles.

space in the fuselage for fuel. It lacked the TV guidance system used in the normal GB-4. Testing began in February 1945, but its small warhead and inaccuracy led to its cancellation. The Navy also looked at a cheaper alternative to the JB-2 with a derivative of its Gorgon family, the Gorgon IIC. An initial batch of 20 missiles was produced by NAMU (Naval Aircraft Modification Unit) and serial production of 100 missiles by the Singer Manufacturing Company in August 1945. Flight tests did not begin until 1946, and the program was downgraded to an exploratory development effort. This design saw extensive use in the post-war years for a variety of technology studies and also served as the basis for a jet-powered target drone.

Guided Glide Bombs

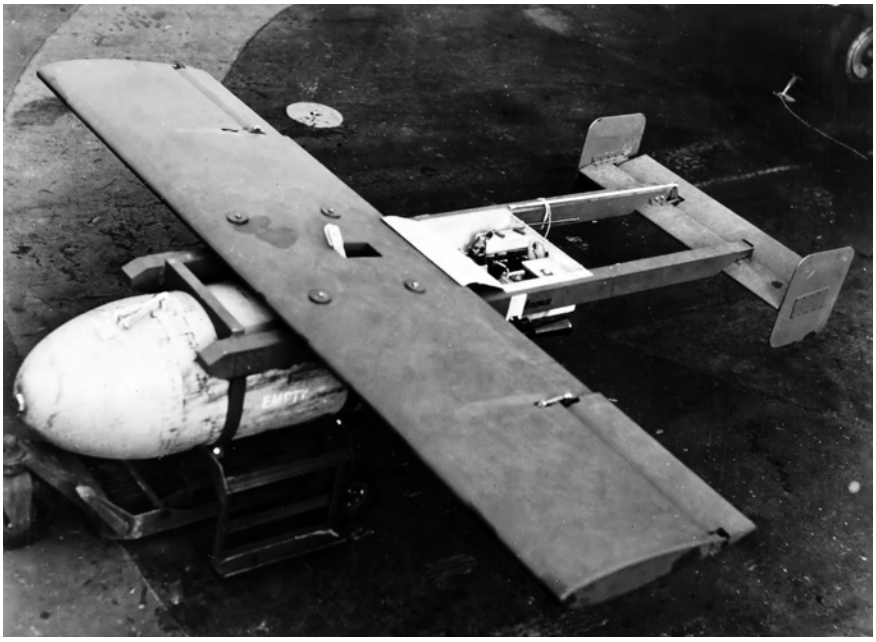
Grapefruit and Batty: The AAF Guided Glide Bombs

In February 1941, the USAAF Materiel Division began preliminary work on a guided glide bomb. The main advantage of a glide bomb was that it could be released several miles from the target, and so the bomber would not be exposed to anti-aircraft artillery near the target. The MX-108 project developed a wing and guidance kit that was installed on a standard 2,000lb general purpose bomb. Early studies examined a simple gyro-based system to maintain a constant azimuth. Tests of a radio-controlled design from Aeronca were conducted at Muroc bombing range in California in December 1941. Gen. Arnold was adamant that he wanted a simple glide bomb with only elementary stabilization. Advanced forms of guidance such as radio control or television, while not prohibited, took second priority.

This B-17E is seen carrying two experimental GB-1 glide bombs during the trials at Eglin Field in 1942.

The new MX-108 weapon was designated as GB (Glide Bomb) on June 24, 1942. GB-1 was configured with a wing over the bomb casing, GB-2 with a mid-wing design, and

The GB-1 consisted of a standard 1,000lb bomb with an Aeronca wing and tail kit. The gyro guidance package was located in the box immediately behind the wing.



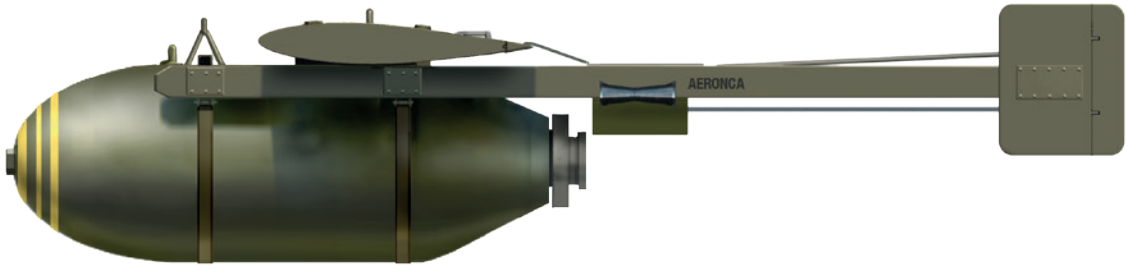
GB-3 with a wing under the bomb. In the event, the GB-1 configuration became the standard design. The Aeronca Aircraft Company of Middleton, Ohio was selected to manufacture the GB-1 airframe parts while the musical instrument firm Hammond Instrument Company produced the gyroscopic stabilization kit.

Tests of the pre-production GB-1 glide bomb began at Eglin Field in August 1942 from B-17F bombers. A total of sixty bombs were dropped. About 70 percent of the tests were deemed satisfactory with bombs dropped from 30,000 feet being sufficiently accurate to hit a medium-sized city and those released from 5,000 feet capable of striking a target about a mile in size. One of the main disadvantages of the GB-1 was that the span of its wings prevented it from being carried internally in the B-17's bomb-bay. Instead, two glide bombs could be carried on external shackles under the wings. This reduced the maximum speed of the B-17F from 310mph to 280mph, and the range from 2,300 miles to 2,150 miles due to drag. In October 1942, the production objective was established at 1,000 GB-1 per month, rising to 2,000 by March 1943. In November 1942, Aeronca was awarded a contract to manufacture 4,300 GB-1 kits with a supplementary contract in March 1943 for 4,000 more kits. Boeing was issued with instructions to incorporate an external bomb rack on future B-17s, as well as to develop a kit to modify older aircraft to deliver the GB-1.

In March 1943, AAF Materiel Command contacted the Eighth Air Force in Britain to determine their requirements. On May 13, 1943, they replied

GB-1, Operation *Grapefruit*, Mission 376, Cologne, May 28, 1944

The GB-1 kit was usually finished in red or yellow when used for tests in the United States. The combat examples were usually painted in olive drab or neutral gray. The bomb casing was finished in the usual olive drab with the yellow bands indicating a high-explosive fill. The GB-1 was 11 feet 7 inches in length with a 12-foot wingspan. It had a glide speed of 230mph and a range of about 20 miles when released from 15,000 feet.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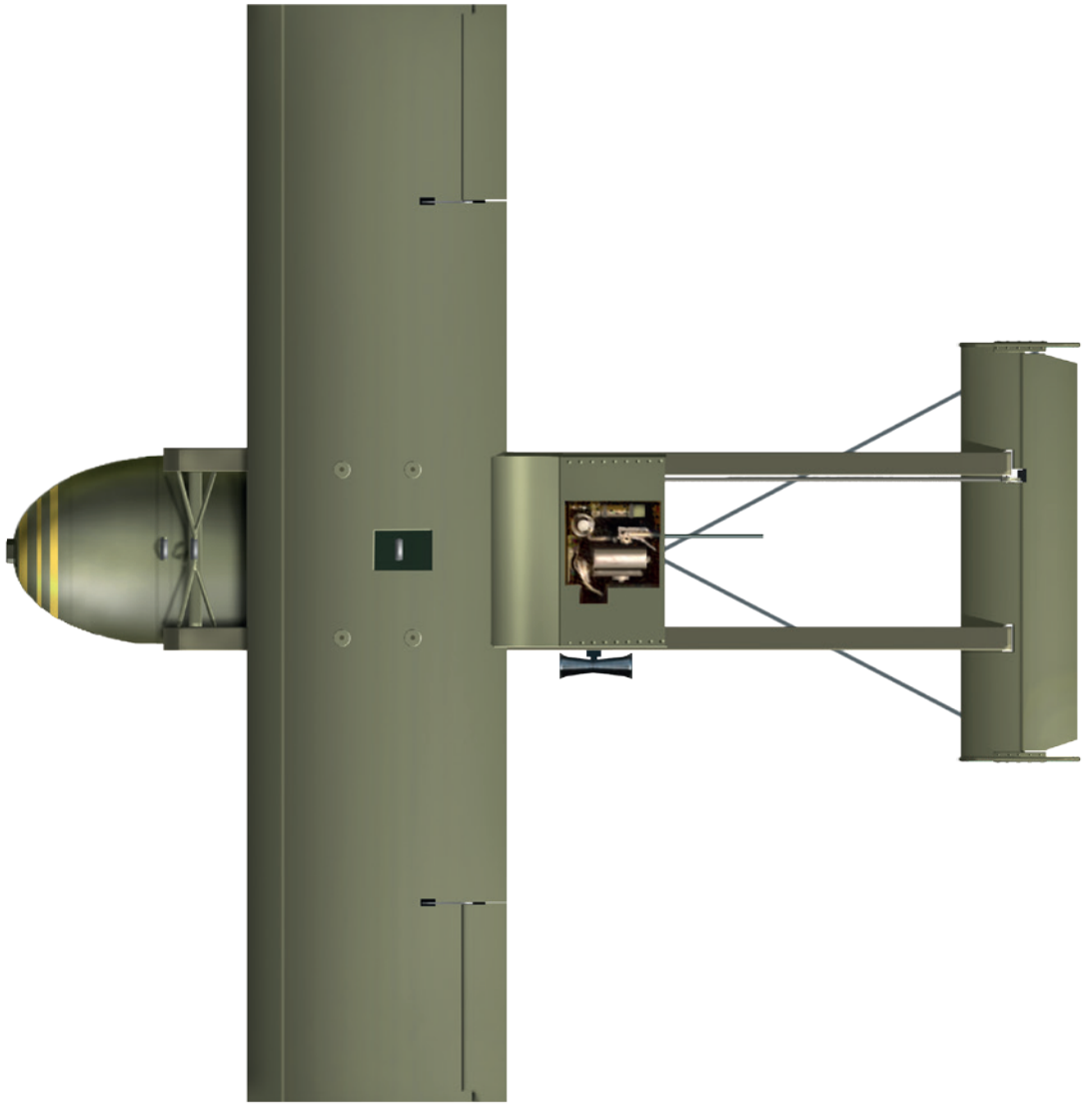
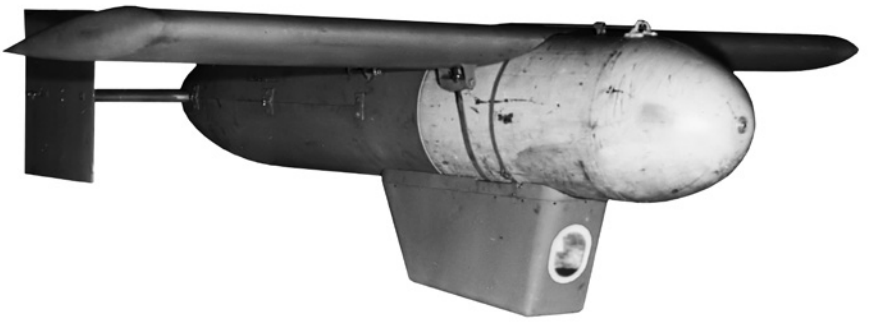


The GB-4 was fitted with a SCR-549-T3 Block 3 camera in the tub under the fuselage in an attempt to offer more precise guidance than simple gyro-based guidance used on the GB-1.



that they had no operational requirement for guided bombs. Their main objections were that the existing tactics called for precision bombing and the GB-1 was less accurate than unguided bombs. In addition, the need to carry the GB-1 on external racks reduced the overall capacity of the B-17 as well as degrading its speed. As a result, Aeronca's contract extension was canceled and production capped at the original 4,300 kits. Regardless of the opinion of the Eighth Air Force, on September 11, 1943, Gen. Arnold insisted that it conduct a glide bomb attack as soon as possible.

The unit assigned to Project Grapefruit was the 41st Combat Bomb Wing, 1st Bombardment Division. There were several delays in staging a Grapefruit mission due to weather, and so the combat debut of the GB-1 was postponed until Mission 376 on May 28, 1944. The target was the Eifeltor railroad marshaling yards at Cologne, with plans to attack the target with 60 B-17 bombers.

The bombers released the GB-1 glide bombs about 20 miles from Cologne. A navigator on a B-17G of the 303rd Bomb Group later reported that "Some of the bombs went into a flat spin almost immediately, and dropped almost straight down. Others turned and flew in various directions and away from the target. A few of them did glide straight as intended and hit the city." A later assessment based on photographic interpretation concluded that 81 bombs were released successfully, 28 immediately spun out of control due to encounters with prop wash, and four were released too late to hit the target. Of the remaining GB-1s, 44 hit somewhere in Cologne, and about 15 hit southwest of the city. No bombs hit the aiming point of the Eifeltor marshaling yards, and at least one hit 17 miles away.

The poor performance of the first Grapefruit mission discouraged the Eighth Air Force from any further GB-1 missions. Inventory remaining in the United States was diverted to the GB-8 and other guided bomb programs, while the rest was scrapped.

Although Gen. Arnold had preferred the development of simple, gyro-stabilized glide bombs, AAF Materiel Command had continued to work on a wide range of precision guidance kits. The most promising short-term development was the MX-607, later GB-4, that used television guidance. The heart of the guidance system was the RCA SCR-549-T2 video camera, developed for a variety of guided weapons. This had a resolution of 120 lines, remarkable at the time, though quite poor by contemporary standards. The GB-4 was one of the few wartime controlled-glide bombs that did not use the standard GB-1 airframe with its characteristic twin booms.

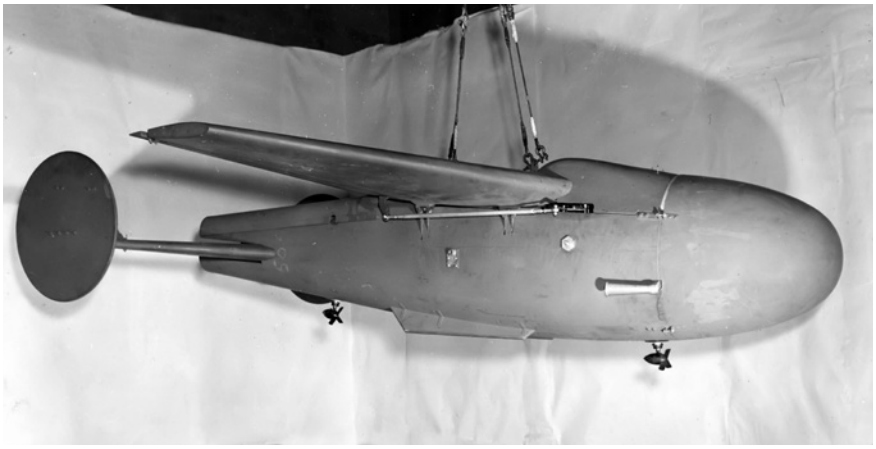
The use of the GB-4 required two bombardiers in the mothership. The lead bombardier located in the nose of the aircraft was responsible for releasing the bomb in the standard fashion. The TV bombardier was located inside the radio compartment of the aircraft and operated a video monitor and radio-command system. The guidance package in the GB-4 broadcast a signal back to the mothership and the TV bombardier could then steer the bomb using a joystick via radio command signals to the GB-4's flight control system. The system had a maximum range of about 80 miles.

In August 1943, five GB-4 guided bombs were tested at Eglin Field revealing a variety of technical problems. Further development resolved many of the issues and standardization was approved on January 15, 1944, with plans to manufacture 2,000 GB-4s. Further tests of the GB-4 in March and April 1944 uncovered lingering reliability problems, mainly related to the fragility of the vacuum tubes (valves) used in the system electronics. Aside from the technical problems, proper operation required an especially well-trained television bombardier and many of the failures were attributed to operator error.

As mentioned above, in June 1944 Gen. Spaatz had made an urgent plea for guided weapons to attack the Crossbow sites in France. A special GB-4 team under the codename Batty was assigned to Project Aphrodite, attached to the 388th Bomb Group at Fersfield in Norfolk. The GB-4 television guidance system worked best when used against targets that had strong visual contrast between the target and the background. Since Heavy Crossbow bunkers did not match this criterion, it was decided to reserve the Batty missions for another time. Poor weather delayed the combat debut of the GB-4 until August 13. The targets were the E-boat bunkers in Le Havre harbor. The first Batty mission consisted of a B-17G mothership carrying two GB-4 guided bombs, a second B-17 control ship monitoring the mission, a pathfinder P-38, and a photo reconnaissance Mosquito. The two GB-4 bombs were released in two passes toward the target, 25 minutes apart. In both cases, the video image was so poor that the bomb could not be accurately steered. The bombs impacted about a mile away from the target.

The GB-8 was based on the GB-1, but fitted with the Hammond radio control system. It was fitted with a set of flares behind the wing to help the bombardier keep track of the weapon during its descent to the target.

The SWOD Mark 7 Pelican used semi-active radar homing for terminal guidance, depending on the radar illumination of the target by the mothership. The two small propeller assemblies are exterior driver units for the Mk. 235 fuzes.



The Mosquito chase plane was accidentally lost when it flew too close to the second GB-4, suffering fatal damage from the explosion of the bomb. After the mission, it was determined that the bomber's own radio equipment had interfered with the command link between the camera in the bomb and the television bombardier.

The second Batty mission was flown on August 17 against the U-boat pens at La Pallice after modifications had been made to the bomber's antenna system. The first bomb failed after the shutter on the camera did not open. The second bomb operated properly, but the sun-glint off the water blinded the TV camera. A mission on August 26 against a railroad bridge near Ravenstein in the Netherlands was aborted due to poor weather, as was the third mission on September 10 against a transformer station at Duren in Germany. The fourth mission on September 12 against targets in Münster failed when the electrical system on the bomb suffered a short-circuit. The fifth mission on September 13 targeted an oil refinery at Salzbergen in Germany. Although there was little cloud cover, there was considerable haze near the ground and the lead bombardier mistakenly released the GB-4 toward neighboring Emsbüren, inadvertently striking a large building in the town. This was the final Batty mission. The failure of the mission led to a decision in February 1945 to halt any further production beyond the 1,200 GB-4s built under the original contract.

The GB-8 guided glide bomb was developed in parallel to the GB-4 as a simpler alternative. Since most of the problems with the GB-4 centered around its immature television guidance system, the GB-8 was developed using the GB-4's radio-command system incorporated into existing GB-1 airframes. Aside from the radio-command system, the GB-8 was fitted with a row of flares to visually assist the bombardier in tracking the descending bomb. The priority of the GB-8 fluctuated over time. In early 1944, some 2,000 were on order from Aeronca, but this was cut back to only 1,000 on July 31, 1944. When the GB-4 was shipped to Britain for the Batty mission, seven GB-8 bombs were sent as well. In the event, the

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GB-4, Operation *Batty*, La Pallice, France, August 17, 1944

The GB-4 was usually finished in overall olive drab or neutral gray. Like most ordnance items, it carried no national insignia. The GB-4 was 12 feet 2 inches in length with a 12-foot wingspan. It weighed 2,536lb and was armed with a 2,000lb AN-M66 general-purpose bomb.

Jim Laurier

GB-4 had greater priority and so none of the GB-8 sent to the ETO was ever used in combat.

A derivative of the GB-1 was designed to launch a torpedo into the water. The GT-1 saw limited service in the Pacific in the final month of the war. The GB-1, GB-4, and GB-8 were the only guided bombs to reach serial production. A number of other experimental types were developed. Most of these used other guidance sensors, and most were based on surplus GB-1 airframes. They are summarized below.

Controlled Glide Bombs

Type	AMC Designation	Guidance	Notes
GB-1	MX-108	Inertial/gyro-stabilization	Original design
GB-2	MX-108	Inertial/gyro-stabilization	Mid-wing equivalent to GB-1
GB-3	MX-108	Inertial/gyro-stabilization	Low wing equivalent to GB-1
GB-4	MX-607	TV/radio command	
GB-5	MX-595	Fairchild photo-electric contrast seeker	GB-1 airframe
GB-6	MX-600	Offner IR seeker	GB-1 airframe
GB-7	MX-605	NRDC radar seeker	GB-1 airframe
GB-8	MX-645	Hammond radio control system	GB-1 airframe with GB-4 radio command system
GB-9	MX-494	Barometric flight control	Ground-skimming glide bomb derived from GB-8
GB-10	MX-618	TV/radio command	GB-4 but with TV in nose
GB-11	MX-614	Inertial/gyro-stabilization	GB-1 with chemical/smoke payload
GB-12	MX-615	Crossely/Hammond photo-electric seeker	originally GB-5C
GB-13	MX-619	Fairchild flare seeker	originally GB-5D
GB-14	MX-613, MX-616	AN/APG-7 radar homing seeker	originally GB-7B
GB-15	MX-717	AN/APW-5 radar + TV	GB-7 derivative

Pelican and Bat: The Navy Guided Glide Bombs

The US Navy developed its own family of guided glide bombs in cooperation with the NRDC (National Research and Development Council). RCA had proposed a television-guided weapon to the NRDC in August 1940 with the associated missile developed under Hugh Dryden at the Bureau of Standards. The first weapon, codenamed Robin, used a television guidance system. Early flight tests were very disappointing due to the immaturity of the television system, with average miss distances of 600 feet or more.

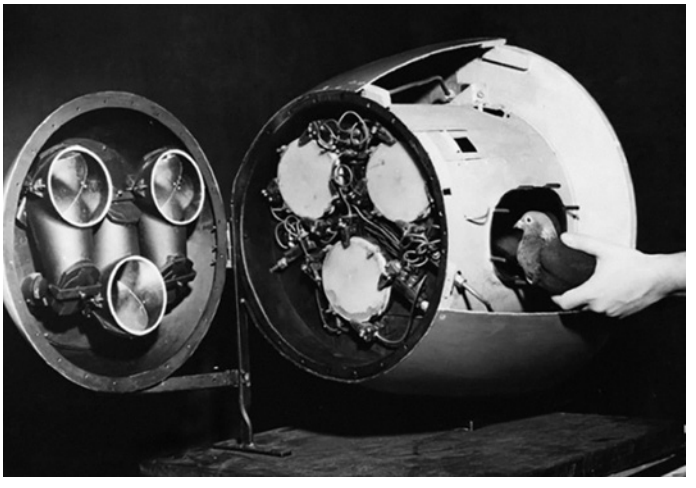
In the spring of 1942, the mission of the glide weapon was accelerated due to the threat posed by German submarines operating against merchant shipping near the American coast. A glide weapon, which could carry a depth charge that could be guided against a surfaced German submarine in the dark using a new radar seeker, was being developed at the Massachusetts Institute of Technology's (MIT) Rad Lab. This initial test version, codenamed Moth,

E

SWOD Mark 9 Bat, VPB-109, Philippines, 1945

The BAT was painted in overall light gray, except for the dielectric nosecone which was left unfinished in its natural glossy white color. The Bat was 11.9 feet in length with a 10-foot wingspan and 1,600lb overall weight. It was armed with an AN-M65 1,000lb general-purpose bomb.

V524
Jim Laurier



One of the oddest guidance schemes for the Navy's air-to-surface missiles was Project Pigeon. The pigeons were trained to peck at the target on one of three small video screens in the nosecone, causing course changes in the missile guidance system. One of these seekers remains in the collection of the Smithsonian Museum in Washington, DC.

used radar-homing against an active radar on the enemy target. The Moth's initial flight tests were conducted in the winter and spring of 1943.

The definitive radar-homing bomb, codenamed Pelican, was fitted with a semi-active radar seeker. The latter required the bomber to illuminate the target with its own radar, and the Pelican homed-in on the radar reflections. The Pelican was test launched from Martin PBM-3 Mariner flying boats, with testing later extended to various other aircraft. By the end of 1943, tests of the MIT radar seeker were promising enough that a group was set up at the Bureau of Standards to prepare the weapon for production. In June 1944, the Liberty ship *James Longstreet* was used as a target and attacked with six pre-production Pelican missiles. The Pelican was designated by the Navy as SWOD (Special Weapons Ordnance Device) Mark 7.

The Navy began to have doubts about the Pelican, since it required the bomber to loiter near the enemy warship to illuminate it with radar. In the meantime, the Rad Lab had proposed a more sophisticated alternative in the form of an active radar seeker. The NRDC had been supporting the development of such a seeker since November 1941 for another weapon program, the Roc. After the bomber identified the target with its own radar, it would cue the active radar seeker on the glide bomb to the target. The active seeker in the missile could then guide itself to the target using its own radar emissions, making it a "fire-and-forget" weapon. The Bat program began in May 1943 using the Pelican's airframe with an active radar seeker produced by Bell Labs. It was subsequently called SWOD Mark 9, or Bomb Mark 57. Live testing of the Bat began in November 1944 with the PB4Y-2 Privateer as its principal launch platform. There were 45 tests conducted against radar-reflecting corner reflectors on land, and ten tests against target ships.

The Bat SWOD Mark 9 used a similar airframe to the Pelican, but was fitted with an active radar seeker in the nose.

The SWOD Mark 9 Bat weighed about 1,600lb with a 1,000lb warhead. The weapon had a maximum range of 15 miles, though more typically it was dropped closer to the target. The enemy ships were identified with the Privateer's APS-2 search radar, and then the operator activated the Mk. 2 Mod. 1 S-band radar seeker on the SWOD. The SWOD Mk. 9 Mod. 0 was followed by the Mod. 1 which incorporated a combined gyro-servo control unit that increased the accuracy of the weapon through faster servo action and increased flight stability.

The PB4Y-2B Privateer was the standard launch platform for the Bat missile during its short operational career in the summer of 1945. The Privateer could carry two Bat missiles, as seen here.

By the end of 1944, the tests were promising enough that the Navy decided to push the Bat into operational service. Three Privateer patrol bomber squadrons were equipped with the PB4Y-2B modified with an AN/APS-2 search radar, Mk.51 Mod. 7 bomb racks, and Bat control equipment. The first of these, VPB-109, was deployed to Palawan to the west of the Philippines in April 1945. Conditions on the island were extremely primitive, making it difficult to keep the sophisticated electronic equipment operable. By this stage of the war, Japanese maritime traffic was minimal. After a failed mission on April 23, VPB-109 staged an attack on Balikapapan harbor on Borneo. Two small freighters were sunk and an oil tank in the Pandansari oil refinery was accidentally struck. The lack of targets prompted the Navy to move the squadron to Yontan, Okinawa. Conditions on Okinawa proved to be even worse than Palawan but with a slightly more ample set of targets nearer to Japan's coast. On May 27, Privateer No. 518, flown by Lt. Leo Kennedy, severely damaged the 970-ton Japanese escort ship *Aguni* with a Bat off the coast of Korea. The missile exploded off *Aguni*'s starboard bow and demolished the area ahead of the bridge, killing 33 sailors. Kennedy's Privateer then sank a 2,000-ton freighter and three smaller freighters using conventional bombs, and he was subsequently awarded the Navy Cross.

The Navy's novel approach to glide bombs was the Glomb, a small, towed glider converted into a guided missile. Three different designs were considered, including this one, the Pratt-Read LBE-1.

The McDonnell LBD-1 Gargoyle was an attempt to develop a radio-command anti-ship missile inspired by the German Hs.293 and Fritz X. It was powered by an Aerojet 8AS-1000 rocket which offered 1,000lb of thrust for eight seconds. The Gargoyle was 10 feet long with an 8½-foot wingspan. It had an overall weight of 1,600lb, including its AN-M59 1,000lb bomb. This example is preserved at the Udvar-Hazy Center at the US National Air and Space Museum in Chantilly, Virginia. (Author)

VPB-109 was relieved by VPB-123 at the end of May 1945; in mid-June 1945, VPB-124 arrived. The use of the Bat from Yontan continued to be troublesome and the squadrons frequently conducted their missions without the missiles. From April to mid-July 1945, a total of 33 Bat missiles were expended, of which there were four hits, four near misses, and seven misses. Many missiles were jettisoned due to engine trouble or low fuel on the Privateer bombers. The return of the experienced VPB-109 in August led to an increased use of the Bat, but no further Japanese shipping was sunk using the missiles, due to the infrequency of encountering targets.

One of the most unusual guidance systems developed for this Navy program was Project Pigeon, conducted with the NRDC starting in 1943. The noted psychologist B.F. Skinner proposed training pigeons to recognize a target using operant conditioning. While strapped inside a nosecone, a pigeon could view three small video screens, and it was taught to peck at the one containing the target. If the target moved, the pigeon would then peck at the other screen. This pecking activated servos in the missile guidance system to change the course of the missile back toward the target. In the event, this project was canceled before reaching the production stage.

Since the Navy had a relatively small number of patrol bombers, there was some interest in a glide bomb that could be delivered by smaller warplanes. Instead of developing a weapon that would be carried under an aircraft, they considered modifying gliders into remotely controlled bombs that could be towed behind a fighter aircraft from the deck of an aircraft carrier. The main attraction of this approach was that a glider bomb, or

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Taylorcraft LBT-1 Glomb

The precise configuration of the missile version of the Glomb had not been decided before the project was terminated. This shows the likely configuration with the rear windows of the glider faired over, and the landing gear ejected after take-off. The Glomb was intended to be towed by carrier-based fighters such as the F6F Hellcat seen in the background. The LBT-1 had a gross weight of 3,930lb with a 2,000lb warhead. It had a 35-foot wingspan and 25-foot length. It had a tow speed of 240mph, a glide speed of 100mph and a maximum speed in a dive of 315mph.

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Glomb, could carry a substantially larger warhead than the AAF's glide bombs. Project George started in 1941 using available sailplanes. Three Taylorcraft TG-6 gliders were converted into XLNT-1 Glombs in September 1942. Following extensive trials of various gliders, contracts were awarded to three manufacturers to each produce a batch of a hundred Glombs, the Pratt-Read LBE-1, the Piper LBP-1, and the Taylorcraft LBT-1. The tow aircraft during trials was usually the F4F Wildcat fighter. There was some skepticism about the project due to the slow speed of the Glombs, as well as technical problems with the guidance system. After only 25 Taylorcraft LBT-1s had been built, the contract was canceled in October 1944. The production of the other two Glombs was also reduced to 35 aircraft each by early 1945. The Piper LBP-1 was canceled in June 1945 and the Pratt-Read LBE-1 in August 1945, after only four had been manufactured.

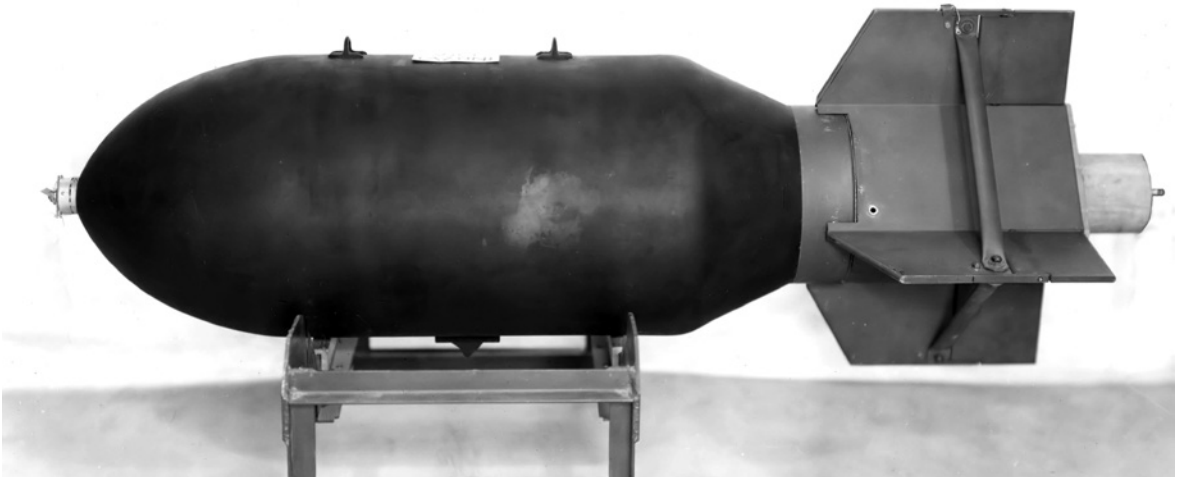
The Navy had a second air-to-surface missile program that was a spin-off from the Glomb glider bomb program. The Gargoyle was inspired by the German Hs.293 and Fritz-X. In September 1944, McDonnell Aircraft was awarded a contract for 400 LBD-1 Gargoyles. The missile weighed 1,500lb, of which 1,000lb was the armor-piercing warhead. The Gargoyle was powered by an Aerojet JATO solid rocket booster and had an effective range of five miles when released from 27,000 feet. Flight tests began in March 1945, but the first fully successful flight did not occur until July 1946. About 200 had been manufactured when production ended in the summer of 1947.

Guided Vertical Bombs

VB-1 Azon

In the summer of 1941, the NRDC began experiments using a lightweight Hazeltine television camera as a means to guide a "dirigible bomb." The tests were successful enough that on December 30, 1941, the AAF and the NRDC began a program for Controlled Trajectory Bombs. At a minimum, the AAF wanted single-axis control in azimuth; ultimately, they wanted double-axis control in both elevation and azimuth.

The initial weapon was called Azon, a contraction of Azimuth Only, and eventually designated as VB-1 (Vertical Bomb). Initial testing at Eglin Field began in May 1942. The original idea was to use the television guidance system, but this technology was not yet mature enough and tests in August 1942 failed. Since radio-command guidance was the most advanced technology available at the time, this was the approach taken. Unlike conventional unguided bombs that rotated for stability, the rotation had to be minimized to make it easier to control the guided bomb. As a result, the guidance system in the VB-1 Azon included an inertial guidance unit consisting of two gyros to control roll and yaw. The bombardier in the parent aircraft controlled the bomb with a joystick via radio commands. He had to maintain visual contact with the bomb, facilitated by the use of a flare in the tail of the bomb. The various elements of the guidance package were contained in a special tail unit that was attached at the rear of a standard 1,000lb bomb. The radio-controlled VB-1 was ready for testing in February 1943. Tests continued through the spring and summer of 1943 to resolve a host of technical and manufacturing problems. The August 1943 tests at Muroc Field, California demonstrated a deflection (azimuth) error



The VB-1 Azon used a standard 1,000lb bomb casing, but was fitted with a special tail section containing the radio-command guidance system.

of 35 feet and an average range error of 427 feet. While there had been very little enthusiasm for guided weapons in bomber units in Europe, the German use of the Fritz-X radio-guided glide bomb in the Mediterranean Theater of Operations (MTO) in August 1943 significantly increased AAF interest, since it clearly demonstrated the potential of such weapons.*

Although the VB-1 Azon was far from perfect, on November 25, 1943, the Union Switch and Signal Company was awarded a contract to manufacture 10,600 VB-1 Azon control assemblies, the extra 600 being earmarked for the US Navy. The early bombs suffered from a variety of durability and reliability problems. For example, the flares had a high failure rate due to moisture absorption until they were delivered in waterproof containers.

The initial tests of production bombs made it clear that it was difficult to accurately predict the range of the bomb due to the variability of time in which the bomb's flight needed to be corrected. Each time the bomb was steered by the bombardier, the process induced drag in the bomb, thereby decreasing its maximum range. Since the duration of the guidance of the bomb was unpredictable until after release, the bomb was invariably inaccurate in range. It was becoming obvious that the VB-1 Azon would be useful primarily against straight, narrow targets such as bridges, rail lines, and railway marshaling yards. Some junior officers at Eglin Field suggested that the VB-1 would be more useful for tactical bombers such as the B-26 medium bomber, rather than for strategic bombers such as the B-17 and B-24. However, since the program had originally been conceived for heavy bombers, these prudent suggestions were largely ignored.

The other tactical problem with the bomb was that the bomber had to remain on a straight and level course for about 30 to 45 seconds while lining up on the target run and stay on another similar course for 30 seconds from bomb release to impact. This was not viewed as acceptable for missions over German industrial targets, which were heavily defended by flak. As a result, the plan was to first conduct operational trials by the 15th Air Force in Italy where flak was not so severe.

* Steven Zaloga, *German Guided Missiles of World War II*, Osprey New Vanguard 276, 2019.

The combat debut of the VB-1 Azon was with the B-17G bombers of the 301st Bomb Group, 15th Air Force on April 24, 1944 against four railroad bridges between Rimini and Ancona. A total of 19 bombs were dropped: three had flare failures and two were dropped by mistake. The remaining 15 bombs were guided part of the way to the target, but all suffered from a lack of control during the final portion of the descent. This was suspected to be due to low battery charges in the guidance assembly, a recurring problem in the early bombs. Nevertheless, the railway line was cut at three locations. Bridge attacks continued in late April with the Fano bridge over the Metauro River being struck on two separate missions. After these four missions, there had been only two direct hits out of 73 bombs expended. One improvement introduced after these attacks was to use two bombardiers, one to release the bomb, and a second trained Azon bombardier to guide the bomb to the target. After two more missions, the total increased to 108 bombs, of which 58 were judged to have operated successfully. Of these, 88 percent had deflection errors of 50 feet or less and a 261-foot CEP (circular error probability, a circle into which at least 50 percent of the bombs fell). While this might not seem particularly good, the CEP of unguided bombs at the time from 15,000 feet was 1,050 feet.

The initial missions led to several tactical changes. Bombardiers were instructed not to apply guidance corrections until the bomb had fallen about two-thirds of the distance to the target in order to minimize the induced drag that affected range accuracy. It was also decided to mix the Azon bombers in with bombers dropping unguided bombs so as not to attract the attention of flak gunners to the Azon aircraft during the perilous minute when the bomber had to remain straight and level. A mission on May 13, 1944 against the Aviso viaduct in the Brenner Pass was assessed to have cut rail traffic through the pass with four VB-1 impacts of the 21 bombs dropped. Later assessments raised doubts about the accuracy of this mission, but the Brenner Pass attack sparked greater enthusiasm in the 15th Air Force for use of the new weapons.

The decision to operate Azon bombers within normal formations led to other problems. The B-17G could carry six 1,000lb bombs, whether guided or unguided. The 15th Air Force decided that the Azon bombers should carry six VB-1 bombs, even though the bombardier could only effectively control one bomb at a time. There was some hope that the guidance signals would help concentrate the six bombs, even though there was little evidence that this would occur. During a June 2 mission against the Oradea railroad marshaling yards in Romania, 12 Azon bombs were controlled by a single

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VB-1 Azon, Sittang River, Burma, December 1944

From December 27, 1944 to March 5, 1945, B-24J Liberator bombers of the 7th Bomb Group dropped 413 Azons on bridge targets in Burma, making 87 hits and destroying or rendering unserviceable 23 bridges, while damaging three more. The VB-1 Azon consisted of a guidance kit attached to the rear of a standard AN-M65 1,000lb general-purpose bomb. The tail kit included a CRW-7 radio receiver to provide guidance commands from the B-24J mothership. The struts between the bomb fins were actually antennae. At the rear of the kit was a flare tube that could contain a T6E1 (white), T7E1 (red), or T8E1 (green) guide flare with an intensity of 1 million candlepower with a duration of one to two minutes. The bomb casing was painted in the usual olive drab, while the tail kit was often painted insignia red. The VB-1 had an overall diameter of 18.8 inches.

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bombardier, though with poor results. Another idea was to tie two Azon bombs together to minimize dispersion. On June 10 a practice mission was conducted against the Italian island of Pianosa, off the coast of Tuscany, using two Azon bombs connected by a 25-foot wire. This did not seem to adversely affect the ballistics of the drop.

Reports from the 15th Air Force led to the suggestion that the dispersion of the Azon bombs would be diminished if the bomb was allowed to rotate like an unguided bomb during the first half of its flight. This could be done by introducing a timer into the guidance assembly that kept the gyro controls from activating until halfway into the descent. This version of the Azon was dubbed Spazon (Spinning Azon) and testing began in November 1944. The test revealed that this decreased bomb dispersion by half. However, these did not reach combat units during the war.

Due to the many problems with the Azon bombs, on July 13, 1944 the 15th Air Force decided to halt further Azon trials. It recommended that the Azon was not suited to strategic targets and should be assigned to tactical bomber units. As a result, the remaining VB-1 bombs were transferred to the B-25 medium bombers of the 446th Squadron, 321st Bomb Group, operating from Corsica. Although the medium bombers promised to offer better accuracy, due to their lower operating altitude, the 446th Squadron was assigned to missions in support of the Seventh US Army following the Operation *Dragoon* landings in southern France. Due to the fast pace of the advance, the army forbade the AAF from staging attacks against bridges, effectively ending this experiment.

The Azon was first used in the ETO by B-24 bombers of the 753rd Squadron, 458th Bomb Group, 8th Air Force. This unit was originally slated to go to the China–Burma–India (CBI) theater, but upon reaching Africa it was diverted to Britain to take part in the pre-D-Day bombings. Sixteen bridge missions were planned prior to the D-Day landings, but half of these were canceled due to bad weather. Of the remaining eight missions starting on May 31, there were four direct hits on bridges and severe damage to six others. Missions in July were halted due to the diversion of most of the Azon equipment to the Aphrodite program described elsewhere in this book. Bridge attacks resumed in August.

As in the MTO, Azons were also deployed with medium bombers, the B-26 Marauders of the 397th Bomb Group, Ninth Air Force operating in support of Patton's Third US Army in northern France. Five B-26 bombers carrying ten Azon bombs attacked the railroad bridges near Chartres on August 4 to impede German movement to the front. The mission highlighted the main tactical drawback of the VB-1 when dropped from 10,000 feet: the vulnerability of the bomber as it flew a straight course during the bombing run. The lead bomber was shot down by flak and three other bombers were damaged. Since most high-value targets such as bridges and marshaling yards were heavily protected by flak, this restricted the use of Azon in the ETO. By this stage, about 2,500 Azons had been expended in the MTO and 500 in the ETO.

The use of the VB-1 in the ETO ended in the fall and winter of 1944, due to cloudy weather, which interfered with most potential missions. The last mission took place on September 13, with B-24s of the 458th Squadron operating against the Hemmingstadt refinery in Germany. Twenty-five VB-1 bombs were dropped, but cloud cover at the last minute interfered with guidance.

Ultimately, the Azon had its greatest success in the CBI. Azon equipped B-24J bombers arrived in India in May 1944, but they were unable to conduct any guided bomb missions through much of the summer and fall, due to monsoons. The first mission by the 7th Bomb Group on December 27 was against the Sittang river bridge on the Rangoon–Mandalay railway line. This had been repeatedly attacked over the previous two years without success. The Azon attack was conducted using a mixture of VB-1 and unguided M65 bombs. Nine Azons made direct hits on the bridge, collapsing the center span and damaging one of the other spans. In contrast to Europe, the Japanese air defenses over many of these sites were not particularly effective. Bridge attacks continued into January 1945 with impressive results. By January 11, 1945, 154 VB-1 bombs had been dropped accounting for 14 bridges. By March 1945, 482 Azons had been dropped, downing 23 bridges and damaging three more. The 7th Bomb Group conservatively estimated that the Azon was at least ten times more effective in bridge missions than conventional bombs. The Azon campaign against the bridges crippled Japanese logistics in Burma. The success of these missions led to a request that the 7,767 Azon bombs stored in Europe be transferred to the CBI. In the event, the return of the monsoon season brought an end to the Azon missions in Burma. The VB-1 was classified as "standard" on April 21, 1945, the first guided weapon officially accepted for regular AAF service. By the end of the war, 50,600 VB-1 bombs had been ordered and 15,271 delivered.

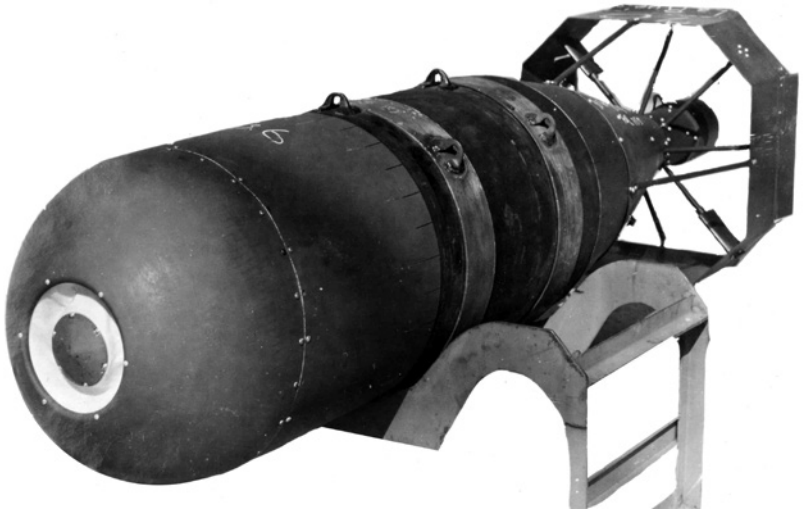
Besides the VB-1, the larger 2,000lb VB-2 was also in development. The initial test batch of 20 was successful enough that a small production order was awarded to the Union Switch and Signal Company. Initial testing of the production bombs began at Tonopah, Nevada in September 1944 and total production reached 150 bombs by the end of the year. Progress on this weapon was slow, since its large size restricted its use from the rear bomb bay of the B-24. There was considerable skepticism that such a large bomb was needed, especially when it could not be used by the B-17. The 10th Air Force in the CBI expressed interest in obtaining 300 monthly, but in the event no serial production was undertaken and the VB-2 arrived too late for operational use in World War II.

The VB-3 Razon was based on the 1,000lb bomb, but the two-axis guidance system required a more elaborate guidance tail kit than the earlier Azon bomb.

VB-3 Razon

It was obvious from the outset of the guided bomb program that two-axis control was preferable to one-axis control, as used in Azon. This was called Razon since it would permit control of both range and azimuth. Although the Razon program officially began in April 1942, no serious work was done until June 1943, after the Azon effort

The VB-6 Felix employed a Bemis infra-red sensor in the nose for terminal guidance.



had matured. Testing of the 1,000lb VB-3 began in September 1944; the 2,000lb VB-4 was put on ice until the VB-3 was demonstrated. The first tests were extremely encouraging, with the mean point of impact only three feet to the side of the target and 17 feet over in range when the bombs were dropped from 15,000 feet. As a result, the VB-3 Razon received a "1A" priority rating on November 1944 to accelerate fielding the weapon, with plans to begin production in January 1945; this was later delayed until March. In January 1945, work began on installation kits to allow the Razon to be delivered by the B-29 heavy bomber. Ultimately, the AAF tests did not take place until June, so the Razon was not ready in time for combat use in World War II.

The VB-10 Roc bridged the gap between glide bombs and vertical bombs with a shroud wing assembly that offered both lift and steering. Here, a pair of VB-10 Rocs are fitted under a B-17G for trials in 1945.

There were a number of other guidance technologies examined for the guided bombs. The VB-5 1,000lb bomb used a "flare-seeking" infra-red seeker. This proved to be beyond state of the art and did not reach the test phase. The most promising alternative was the VB-6, better known by its "Felix" codename which used an infra-red bolometer developed by Dr. Alan Bemis at MIT to pick up the heat signature of a target. Tests were promising enough that in August 1945, the 20th Air Force requested the dispatch of 300 VB-6s to Tinian Island in the Northern Marianas for use against Japan. Ultimately, only 375 of the 1,000 bombs ordered were delivered before the end of the war and none were used in combat. There were some trials of the bomb after the war, and in 1948, the Air Force looked at the Felix guidance system for future use with air-to-surface missiles.

The Roc program undertaken by the AAF and NRDC studied five different precision guidance options for a medium-angle bomb under the designations VB-9 through VB-12. After studying a bomb with cruciform wings, the development shifted to a type of lifting shroud around the center of the weapon. Development focused on the VB-10 television-guided version, but this was still in the test stage in March 1946. The largest guided bomb of the war was the VB-13 Tarzon, a combination of the British Tallboy 12,000lb penetrating bomb with Razon guidance. Although Tarzon did not prove ready for combat in 1945, this bomb was successfully used in Korea from B-29 bombers under the new designation ASM-A-1.

The MX-674 Tarzon guided bomb was not ready for combat in World War II, but it was used extensively for bridge-busting during the Korean War from B-29 bombers. It was 21 feet long and based around the 12,000lb T10 general-purpose bomb.

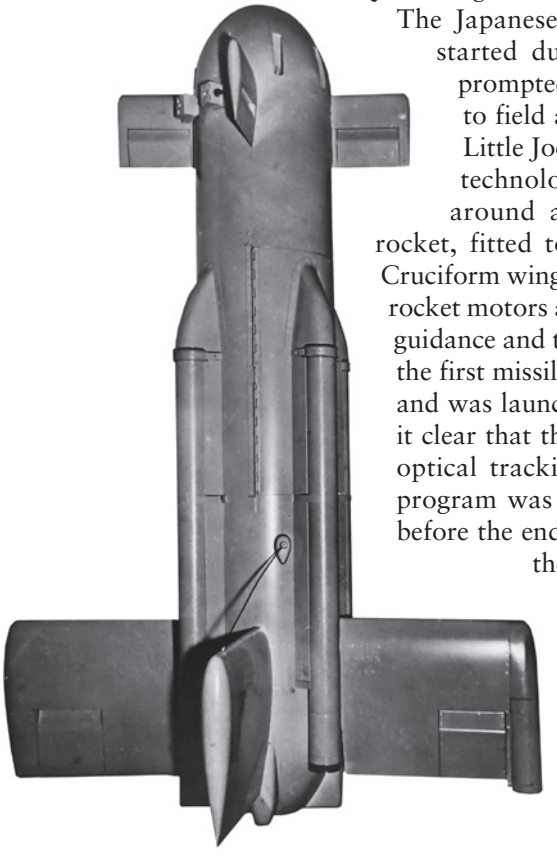
AAF Guided Vertical Bombs			
VB-1	Azon	MX-225	1,000lb bomb, radio-controlled in azimuth
VB-1	Spazon	MX-593	1,000lb bomb, radio-controlled in azimuth, spin stabilized
VB-2	Azon	MX-590	2,000lb bomb, radio-controlled in azimuth
VB-3	Razon	MX-591	1,000lb bomb, radio-controlled in range and azimuth
VB-4	Razon	MX-592	2,000lb bomb, radio-controlled in range and azimuth
VB-6	Felix	MX-612	1,000lb bomb, infra-red seeker
VB-7	Razon		1,000lb bomb, Razon controls plus camera
VB-8	Razon		2,000lb bomb, Razon controls plus camera
VB-9	Roc	MX-602	1,000lb bomb with radar seeker
VB-10	Roc	MX-601	1,000lb bomb, TV control
VB-11	Roc	MX-604	1,000lb bomb infra-red seeker
VB-12	Roc	MX-603	1,000lb bomb, visual control
VB-13	Tarzon	MX-674	12,000lb bomb, radio-controlled in range and azimuth

Air Defense Missiles

The successful German use of radio-guided bombs and missiles against Allied ships in the Mediterranean in 1943–44 led to US Navy interest in the development of a long-range surface-to-air missile that could destroy the enemy bomber before it could release its guided weapon. Several different projects were in development, including Operation *Bumblebee* to study ramjet-powered missiles and Project Lark to study a radar-guided, rocket-powered missile. The Lark was ready first, so in March 1945, Fairchild was given a contract to build 100 missiles using radio-command guidance with an AN/DPN-7 semi-active radar seeker for terminal homing. A parallel effort was started with Convair in June 1945, using beam-riding guidance with an

Development of the Lark began in 1944 to deal with the threat of anti-ship missiles, which were launched by German bombers. Its evolution continued after the war and this example is seen at the Navy's Point Mugu test range in March 1949. The missile was 12½ feet long with a weight of 1,360lb.

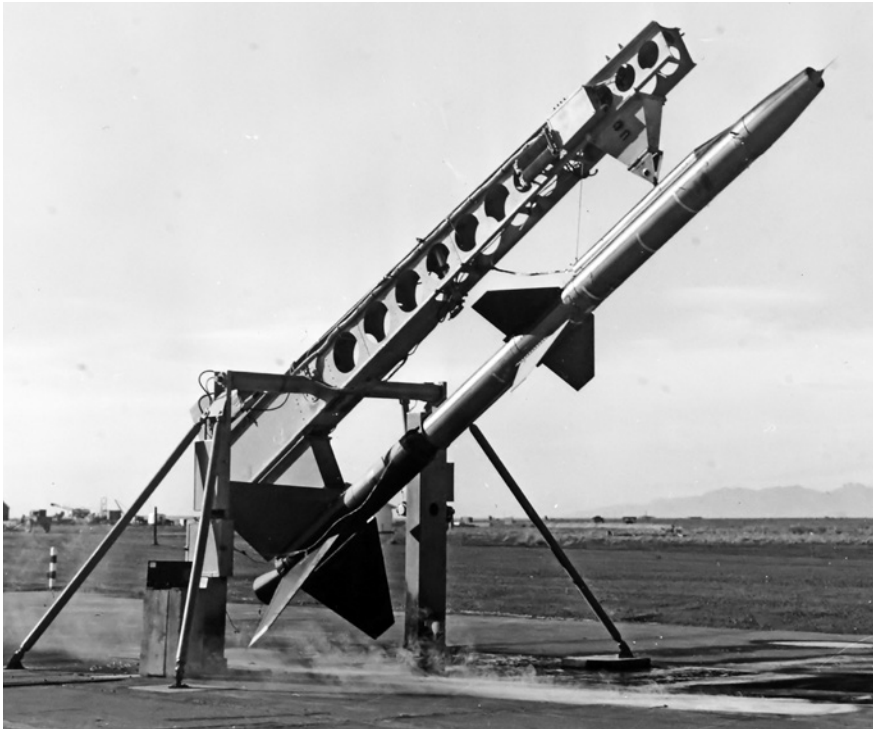
AN/APN-23 radar-homing seeker. None of these missiles was ready before the end of the war, but the Lark went down in missile history when it scored the first surface-to-air missile interception in January 1950, shooting down a QB-17 target drone.



The Little Joe was a crash program at NAMU, which was started to quickly develop an anti-aircraft missile to defend against the Kamikaze threat in 1945. It was 8½ feet in length and weighed 591 to 651lb, depending on the rocket boosters. It was armed with a 100lb AN-M30 bomb detonated by a M166 proximity fuze.

The Japanese Kamikaze attacks against US Navy ships, which started during the Philippines campaign in October 1944, prompted the US Navy to start a "quick and dirty" program to field an improvised anti-aircraft missile called the KAN-1 Little Joe. It was developed by NAMU by putting the existing technology into a simple missile. The fuselage was based around a standard Aerojet Jet-Assisted Take-Off (JATO) rocket, fitted to a standard 100lb bomb with a proximity fuze. Cruciform wings and tails were added along with four 3¼-inch solid rocket motors as boosters. The weapon used simple radio-command guidance and the program took only five weeks to design and build the first missile. The first test example was ready on June 21, 1945 and was launched from Island Beach, New Jersey. The tests made it clear that the JATO propulsion resulted in so much smoke that optical tracking of the missile was difficult. Although the test program was eventually successful, the Little Joe was not ready before the end of the war, and it was canceled in 1946 in favor of the more sophisticated Lark.

Meanwhile, in May 1944, the US Army had begun to examine the need for a surface-to-air missile program of its own, though the program was not officially approved until January 26, 1945 as Project Nike. Due to the low priority of the program, no hardware was ready at the end of the war and only preliminary design studies had been undertaken. The first Nike test launch was



The AAF's MX-606 GAPA examined a variety of propulsion systems for air defense missiles. This is a Series 602 ram-jet test missile after the war at Alamogordo Guided Missile Test Base, New Mexico, later renamed Holloman AFB.

conducted on September 17, 1946 and the first interception of a QB-17 target drone by a Nike Ajax was made on November 27, 1951.

The AAF also examined the possibilities of developing an anti-aircraft missile as the GAPA (Ground-to-Air Pilotless Aircraft). The original idea was to use a remotely piloted drone aircraft, but the slow speed of this option led to the study of rocket- and ramjet-powered missiles. The first test of the Boeing GAPA was on January 13, 1946 and the program eventually became the Bomarc missile.

Air-to-Air Missiles

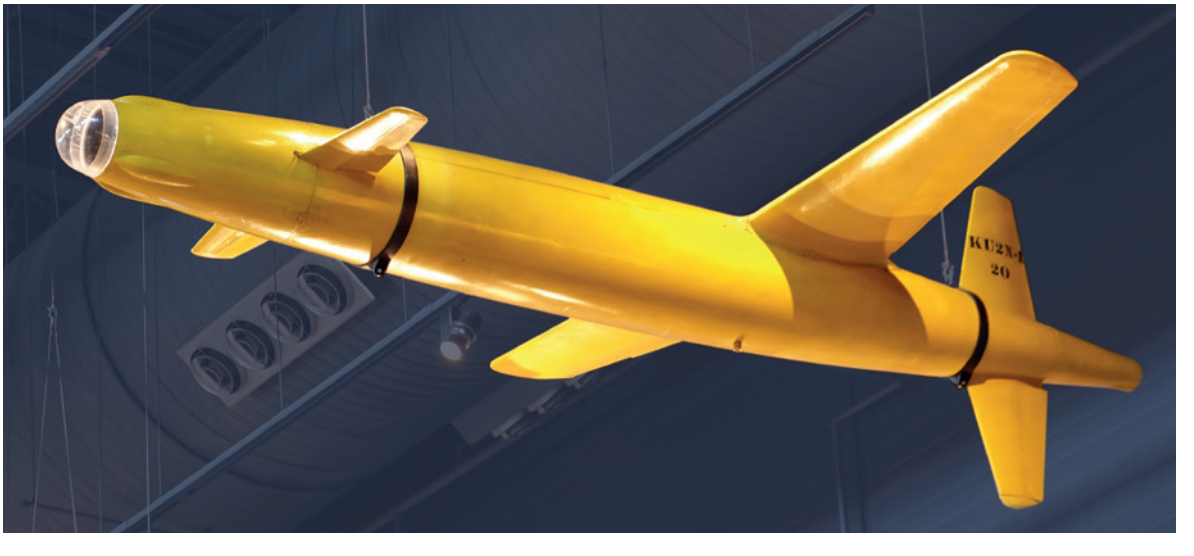
In March 1941, the Engineering Division of the AAF Material Center proposed to develop a high-speed ramming aircraft to destroy enemy aircraft. This small aircraft would be contained within a larger bomber or cargo aircraft, and then launched from beneath the mothership. This concept was put on ice until February 1943. To test the idea a PQ-12A target drone was fitted with a TV camera and a 500lb bomb. After take-off, the PQ-12A was radio-controlled from an accompanying Cessna UC-78 Bobcat. The target was a PC-8 target drone. The PQ-12A approached the PQ-8 while being monitored over the TV, and when it came

The PQ-12 target drone was modified as a proof-of-concept for a guided air-to-air missile in 1943 by fitting it with a 500lb bomb warhead and a guidance camera. The converted PQ-12A missile can be seen in the foreground with two PQ-12 optionally-piloted target drones in the background.

The AAF developed the JB-3 Tiamat as an air-to-air missile from 1944. It is seen here under the wing of a JB-26 Invader test aircraft at Holloman AFB, New Mexico in August 1947 during flight trials.

close to the target, the warhead was remotely detonated about 75 feet away, causing it to crash. Although this proved the concept of an air-to-air missile, there was considerable skepticism about the use of a slow propeller-driven aircraft in this role.

The AAF began the MX-570 air-to-air missile program in January 1944, issuing a contract to Hughes Aircraft. This was subsequently designated as the JB-3 Tiamat. The missile was subsonic, and employed solid rocket propulsion. By later standards, it was quite large, weighing 625lb with a 100lb warhead. A test version of the Tiamat with a booster stage was launched from the new range at Wallops Island on July 4, 1945 and the first air-launch was conducted on August 6 from a JB-26 Invader bomber. The early trials experienced considerable difficulties with the rocket motor, and the planned semi-active radar seeker was significantly delayed.



The US Navy's first air-to-air missile was the Gorgon II with a television mounted in the nose for guidance. This rocket-powered Gorgon IIA is preserved at the Udvar-Hazy Center at the US National Air and Space Museum in Chantilly, Virginia. (Author)

The wartime air-to-air missiles were too large for most fighter aircraft. After the war, attention turned to smaller missiles, such as the Ryan Firebird (MX-799), seen here under the wings of an F-82 fighter at Holloman Air Force Base.

The Navy's BuAer began its own study of an Aerial Ram in March 1943 as part of its Project Gorgon. The Gorgon was envisioned as a family of missiles that could be used in the air-to-air or air-to-surface role. It was a large missile, weighing 760lb, that was powered by a Westinghouse 9.5A turbojet engine. For guidance, the Gorgon II was radio-command guided using an RCA Block 1 television system as its sensor. Due to problems with the turbojet engine, the initial Gorgon IIA was fitted with an Annapolis solid rocket motor while the Gorgon IIB was scheduled to receive the delayed turbojet. Unpowered, unguided tests of the Gorgon IIA from a PBY-5A Catalina began on January 17, 1945, and powered tests on March 8. A guided, powered test with the TV guidance system in place was conducted later that month. There was considerable skepticism over the operational need for such a large missile in the air-to-air role, and in April, the head of the Navy's BuAer, Rear Adm. DeWitt Ramsey, downgraded the program to an engineering demonstration program. In the event, the only aspects of the Gorgon program to receive serious attention were the Gorgon IIC "Junior Buzz Bomb" and the TD2N target drone.

Neither the Tiamat nor Gorgon II were practical air-to-air missiles due to their size, which necessitated the use of a medium bomber as the launch platform. It was not until 1946 that more realistic programs began, notably the Air Force Firebird and Falcon, and the Navy's Sidewinder and Sparrow. These benefited from the advances that had been made in guidance technology in the previous year that allowed for the design of missiles small enough to be launched from a fighter aircraft.

Surface-to-Surface Ballistic Missiles

Robert Goddard was the pioneer of liquid-propelled rockets in the decades before World War II. However, he was unable to convince the US Army of the utility of this technology. The lack of Army interest in surface-to-surface missiles was largely due to the heavy investment by the AAF in bomber aircraft which fulfilled the long-range bombardment mission. German development of ballistic and cruise missiles prompted the US Army's Ordnance department to re-examine this issue in May 1944 as Project ORDCIT (Ordnance/

The US Army's earliest missile was the small Private, first launched in December 1944. It is seen here below the much larger Corporal that was first launched in October 1945. These two missile mock-ups were put on display at the Jet Propulsion Lab in California for Maj. Gen. Gladeon M. Barnes, then chief of the Army Ordnance Research and Development Service when he visited JPL in January 1945. The figure on the left is JPL Acting Director Frank Malina.

California Institute of Technology). A group of scientists at CIT under Dr. Theodore von Karman had been studying the use of rockets for high-altitude research since the late 1930s and they had proposed a long-range missile to the army. A number of ballistic missiles were proposed starting with the small Private, and leading to larger designs such as the Corporal. Two dozen of the elementary Private A were launched in California in December 1944. Wind tunnel tests of Private and Corporal began at Aberdeen Proving Ground, Maryland, in February 1945 and test launches of the Private F began in April. Due to the range requirements, a new proving ground was established in the desert near White Sands, New Mexico. The booster section of the Corporal missile was the first rocket tested at White Sands on September 26. In the event, Project ORDCIT started much too late to reach the production stage, and US Army ballistic missiles did not enter service until 1954.

Analysis

US guided missiles of World War II are not as well known as their more famous German counterparts. The Third Reich developed the V-1 cruise missile and V-2 ballistic missile as alternatives to their ineffective bomber force. Neither the US Army Air Force nor US Navy saw the need to devote exorbitant resources to bombardment missiles, since their conventional aviation forces proved to be highly effective in 1944–45. The single most expensive German weapon program of the war was the V-2 ballistic missile; the most expensive American programs were the B-29 bomber and the atomic bomb. The V-2 was a technological marvel, but it was ineffective as a weapon; the B-29 and atomic bomb were war-winners.

The US armed services spent about $34 million on missile research in World War II, with the Navy accounting for the lion's share at $19.7 million, the AAF at $10.8 million, and the Army at a paltry $3.4 million. This was less than 5 percent of the annual research funding at its peak.

The only program to have significant results on the battlefield was the AAF's VB-1 Azon, which played a major role in crippling Japanese logistics in the Burma theater in 1945, with its short but effective bridge-busting campaign. The Navy's Bat anti-ship missile was the most sophisticated missile to have emerged during the war, but it arrived too late to have any impact. Several of the larger missile programs – the Navy's assault drone program, the AAF's Aphrodite/Castor aircraft missiles, and the AAF's glide bomb programs – proved to be inconsequential. The main problem with wartime programs was the immaturity of guidance technologies, and the lack

of battlefield durability of systems that depended on vacuum tube electronics. The most important outcome of the US guided missile programs of World War II was the establishment of the technological basis for American Cold War missile programs in the 1950s. Many missile technologies, including radar, infra-red, and inertial guidance, were in their infancy in World War II, and reached maturity in the early 1950s with advances in more durable solid-state electronics. For the US armed services, World War II was the dawn of the missile age of warfare.

Further Reading

There has been no comprehensive survey of US guided missiles in World War II, although many aspects of this subject have been covered in published books and articles. This book was based primarily on archival records located at the National Archives and Records Administration in College Park, Maryland. The documents were primarily located in the Army Air Force Research and Development files (Record Group 18), the Sarah Clark/Army Air Force Materiel Command collection (RG 342), and the Admiral Delmar Fahrney/Bureau of Aeronautics collection (RG 72). The author also consulted the Gen. Carl Spaatz Papers at the Library of Congress in Washington, DC.

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